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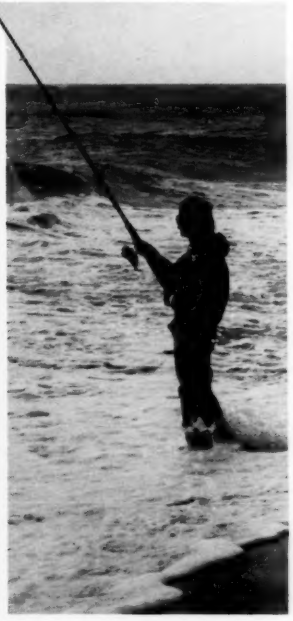

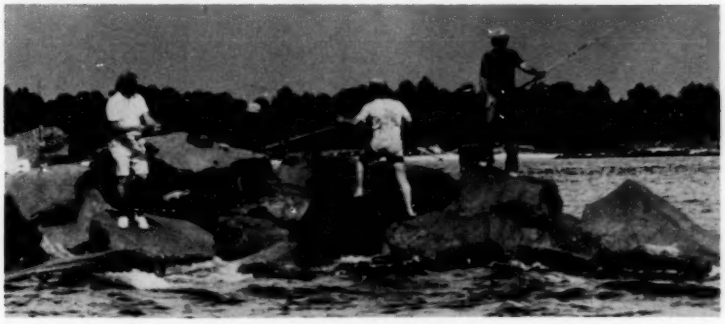

Marine Recreational Fisheries and Fishing

Marine Fisheries REVIEW

On the cover: Views of marine recreational fisheries. NMFS, NOAA photos.

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Marine Recreational Fisheries and Fishing

A Special Issue of the *Marine Fisheries Review*

W. L. HOBART, *Editor*

Introduction

Marine angling is an important form of recreation for millions of U.S. citizens and provides many thousands of enjoyable hours and thousands of pounds of high quality food items. Specific data on some of those aspects of the sport are provided in several NMFS publications reviewed or referenced in the "Developments" or news section of this issue.

Marine angling is also a very broad-based activity: The target species and fishing techniques are many, the anglers cut across all levels of society, and the areas fished range from urban settings to the high seas. The research on marine recreational fishes and fisheries is equally diverse, and much of this diversity can be found in the articles in this special issue of the *Marine Fisheries Review* on marine recreational fisheries—*MFR* on MRF.

In the past the *MFR* has occasionally published individual articles on various aspects of MRF. This time a particular issue was set aside for NMFS authors to present reviews or reports on their research activities. In some cases, time constraints did not permit participation, but to those who were able to contribute I extend my thanks. A few related papers from nonagency authors are also included. I am grateful to all the authors and reviewers for their diligence in preparing and critiquing the articles. The task was great, for this issue is about double the normal size of the *Review*. I hope that it will be a useful reference.

W.L.H.

Marine Recreational Fisheries in the Southeastern United States: An Overview

RONALD L. SCHMIED and EDWARD E. BURGESS

ABSTRACT—Marine recreational fishing in the southeastern United States is an outdoor recreational activity of increasing popularity, economic significance, and consequence to the region's fishery resources. In 1985, over 11 million anglers made 44 million fishing trips in the South Atlantic and Gulf and caught 222 million fish. Thirty-five percent were landed weighing over 131 million pounds, representing 40 percent of total edible finfish landings in the region. In 1985, the region accounted for 40 percent of all U.S. saltwater anglers, 62 percent of all trips, and 50 percent of the total number of recreationally caught fish. Direct expenditures by South Atlantic and Gulf anglers in 1985 were estimated to be nearly $3.4 billion. These expenditures are estimated to have generated an additional $1.5 billion in value added and supported over 42,000 person-years of employment in marine recreational fisheries related support and service industries. Additional detailed discussion of the nature and extent of marine recreational fishing in the South Atlantic, Gulf of Mexico, Puerto Rico and U.S. Virgin Islands is presented.

Purpose and Methods

This paper describes the nature and extent of marine recreational fisheries (MRF) in the southeastern United States and briefly highlights some of the problems and opportunities surrounding the future management of saltwater sport fisheries in the region. This region includes coastal states in the South Atlantic (North Carolina, South Carolina, Georgia, Florida east coast) and Gulf of Mexico (Florida west coast, Alabama, Mississippi, Louisiana, and Texas), as well as the U.S. Virgin Islands (U.S.V.I.) and Puerto Rico in the Caribbean.

Unless otherwise noted, the principal source of statistical information used in this paper is the National Marine Recreational Fisheries Statistics Survey conducted by the National Marine Fisheries Service (NMFS) in the South Atlantic and Gulf annually since 1979. In 1979 and 1981, surveys were conducted in the Caribbean, but since 1981 Caribbean data are incomplete in some respects, this paper cites only 1979 data.

Background

The demand for outdoor recreation increased dramatically in the United States in the years following World War II. Much of this increased demand stemmed from a marked rise in affluence and mobility of Americans, and from attendant increases in leisure time and discretionary income. Concurrently, many Americans were moving from cities to suburbs and from the hinterlands to the coasts. Undoubtedly, the proximity of larger portions of the population to water is partial explanation for the fact that by 1960, over 44 percent of outdoor recreation participants preferred water-based recreation activities. (U.S. Outdoor Recreation Resources Review Commission, 1962). Participation in water-based recreation continues to grow at a faster rate than the U.S. population (HCRS, 1979).

Ronald L. Schmied and Edward E. Burgess are with the Southeast Regional Office, National Marine Fisheries Service, NOAA, 9450 Koger Boulevard, St. Petersburg, FL 33702.

Based on available data, it is evident that saltwater sport fishing was, and continues to be, pursued by growing coastal populations to partially fulfill the desire for water-based recreation. In the United States, participation in saltwater sport fishing increased 2.7 times and related expenditures grew sevenfold between 1955 and 1980 (Table 1). Major advances made during this period in the design and manufacture of recreational boats, outboard motors, navigational equipment and sport fishing gear further contributed to increased participation in saltwater sport fishing.

In the southeastern United States, marine recreational fishing has become an outdoor recreation activity of considerable significance in terms of participation, catch, and economics. In 1985, more than 11 million anglers made over 44 million sport fishing trips and caught an estimated 222 million fish in this region. Over 35 percent of these fish were landed, weighing in excess of 131 million pounds. Recreationally landed fish represented about 40 percent of total regional landings (commercial and recreational combined) of edible finfish. Recreational harvest of shellfish and crustaceans in the southeast is significant but of unknown magnitude.

Notably, the southeast region has accounted for a major portion of the total U.S. growth in saltwater sport fishing participation, catch, and expenditures since 1955. In 1985, the southeast accounted for over 40 percent of the nation's saltwater anglers, 62 percent of all trips, 50 percent of the catch in number of fish and over 55 percent of all direct expenditures made nationally by saltwater anglers. These regional and national per-

Table 1.—Participation and expenditures for saltwater sport fishing in the United States[1].

Criteria	1955	1960	1965	1970	1975	1980
Number of saltwater sport fishermen[2]	4,557,000	6,292,000	8,305,000	9,460,000	13,738,000	13,332,000
Number of recreation days of saltwater sport fishing	58,621,000	80,602,000	95,837,000	113,694,000	167,499,000	160,678,000
Expenditures of saltwater sport fishermen ($U.S.)	488,939,000	626,191,000	799,656,000	1,224,705,000	3,095,369,000	3,611,373,000

[1]Data from 1970, 1975 and 1980 editions of "National Survey of Fishing and Hunting and Wildlife Associated Recreation," U.S. Dep. Int., Wash., D.C.
[2]Since the survey defined saltwater sport fishermen differently in several years, the data have been adjusted to represent participation and expenditures for anglers 12 years old and older.

spectives are perhaps slightly underestimated since data for the U.S. Virgin Islands and Puerto Rico are not available for 1985. The importance of marine recreational fisheries in the southeast warrants closer examination of participation, catch, and economic indicators.

The Setting

In 1985, an estimated 11.4 percent (6.5 million) of the 56.8 million Americans residing in coastal states of the South Atlantic, Gulf of Mexico and Caribbean (Puerto Rico and U.S.V.I.) participated in marine recreational fishing. Another 4.6 million visiting anglers also fished in the region. This significant participation continues to be influenced by at least three major factors.

First, the rapid population growth of the southeast between 1955 and present, linked with the area's warm climate, diverse and abundant marine fishery resources, extended fishing seasons, and strong historic participation trends in fishing, boating, and other water-based recreation activities set the stage for strong saltwater sport fishing participation levels.

Second, the substantial fishing infrastructure that occurs along the region's estimated 30,000 miles of shoreline (Lane, 1986) provides the physical means for residents to participate. In 1985, the region had over 150 coastal fishing piers, 1,630 coastal marinas (Ross[1]), over 2.5 million private recreational boats, 950 charterboats, 180 headboats, hundreds of diveboats and small guideboats, untold miles of "fishable" beaches, bridges, and jetties, and an unequaled assemblage of artificial fishing reefs. Increased state funds under the Wallop-Breaux program are being used to further upgrade the quantity and quality of boating and fishing facilities.

Third, growing recognition of the importance of saltwater sport fishing as both a resident outdoor recreation activity and tourist attraction has precipitated expanded public education and information programs (literature, television shows, fishing clinics, etc.) that have helped "socialize" residents and tourists into marine recreational fishing activities.

Marine Recreational Fishermen

Marine recreational fishing (MRF) in the southeastern U.S. is primarily an activity involving family and friends participating in small groups averaging 3-4 people. According to a social-economic study of MRF in 1981 (KCA, 1983), marine anglers in the South Atlantic and Gulf averaged 31-32 years of age and were primarily white males having annual household incomes between $15,000 and $35,000. Fishermen having personal incomes between $10,000 and $15,000 were the most avid anglers averaging 26.3 fishing days per year in the Atlantic area and 32.3 days in the Gulf. The overall average participation rate was estimated to be 23.5 days per year for the Atlantic and 25.9 days per year in the Gulf in 1981. More recent social and economic data do not exist, so it is unclear how these general parameters might have changed since 1981. Comparable data are not available for Puerto Rico or the U.S. Virgin Islands.

Dramatic efforts by private groups[2] like the Coast Conservation Association and United Sport Fishermen are underway to better organize saltwater anglers in the Gulf and South Atlantic, but as of 1981, only 5 percent of all anglers were estimated to be members of fishing clubs or related organizations (KCA, 1983). Interestingly, only three states in the southeast currently require saltwater sport fishing licenses. Texas requires all anglers to obtain a general sport fishing license and a saltwater stamp. Louisiana requires resident and nonresident marine recreational fishermen to purchase both a basic fishing license and a saltwater angling license. Alabama requires nonresidents to purchase a fishing license which allows them to fish in fresh-, brackish- or saltwater. Alabama residents need no license to fish in saltwater.

Sport Fishing Patterns

In 1985, an estimated 2.4 million residents of U.S. South Atlantic coastal states, and 4.0 million Gulf coastal state residents participated in marine recreational fishing. These participation rates reflected a 14 and 38 percent increase, respectively, over 1979 and 1984 average participation rates for the South Atlantic and Gulf areas. Collectively, coastal state residents accounted for 78 percent of the 44 million fishing trips made in the Gulf and South Atlantic areas in 1985. An estimated 4.6 million visitors accounted for the remaining 10 million sport fishing trips. Ninety-seven percent of the estimated 679,000 saltwater fishing trips made in Puerto Rico and the U.S.V.I. in 1979 were made by residents.

As Table 2 shows, residents of the South Atlantic and Gulf fished most frequently from private boats and man-made structures. Visiting anglers in the South Atlantic were most apt to fish from beaches, banks, party boats, and charter-

[1]Ross, N., and P. Joyce. 1987. Information regarding International Marina Association data base. Personal commun., Middletown, R.I.

[2]Mention of commercial firms, products, or private organizations does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 2.—Characterization of marine recreational fishing in the South Atlantic, Gulf of Mexico, and Caribbean[1].

Characteristic		South Atlantic		Gulf		Caribbean			
						U.S.V.I		Puerto Rico	
1. MRF licenses		None required by NC, SC, GA, or FL		TX & LA require res. & nonres. licenses. AL requires nonres. license.		None required		None required	
2. No. of participants (1985)									
Resident		2,423,000		3,959,000		2,300		83,900	
Visitor		2,272,000		2,302,000		500		6,200	
3. No. of private recreational boats (1985)[2]		962,425		1,547,960		2,718		23,025	
4. No. of paying passenger vessels, fishing piers & coastal marinas (1985-86)									
Charterboat		492		441		8		7	
Headboat		99		78		1		0	
Fishing piers		82		67		0		0	
Coastal marinas		660		915		31		24	
5. Number of saltwater tournaments (1985-86)[3]		North Carolina	= 30	Florida (w.)	= 58	5		20	
		South Carolina	= 82	Alabama	= 15				
		Georgia	= 5	Mississippi	= 9				
		Florida (east)	= 90	Louisiana	= 6				
				Texas	= 69				
6. Top five species sought (1985)		Spotted seatrout		Spotted seatrout		Other fishes[4]		Other fishes[4]	
		Bluefish		Red drum		Dolphins		Ladyfish	
		Red drum		Other fishes[4]		Mackerel/tunas		Jacks	
		Other fishes[4]		Groupers		Cero mackerel		Herrings	
		King mackerel		Sea basses		King mackerel		Snappers	
7. Most frequently caught fish as percent of total fish caught (1985)		Spot	16%	Saltwater catfishes	14%	False pilchard	31%	Herrings	19%
		Black sea bass	8%	Spotted seatrout	10%	Sea basses	6%	Scaled sardine	12%
		Atlantic croaker	7%	Atlantic croaker	9%	Atlantic croaker	6%	Other fishes[4]	6%
		Bluefish	7%	Sand seatrout	7%	Coney	5%	Anchovies	5%
		Hearings	7%	Pinfish	7%	Mackerel/tunas	5%	Ballyhoo	4%
8. Most frequently landed fish as percent of total fish landed (1985)		Spot	21%	Spotted seatrout	19%	False pilchard	48%	Anchovies	9%
		Black sea bass	10%	Sand seatrout	12%	Mackerels/tunas	6%	Herring	8%
		Bluefish	9%	Atlantic croaker	8%	Cero	6%	Ballyhoo	6%
		Atlantic croaker	6%	Black sea bass	7%	Red hind	4%	Balao	2%
		Mullets	5%	White grunt	6%	Tunas	4%	Bar jack	5%
9. Total number of fish caught	1979	101,595,000		162,279,000		81,300		2,664,000	
	1980	77,477,000		154,176,000					
	1981	54,964,000		131,407,000					
	1982	76,844,000		154,405,000					
	1983	77,955,000		109,745,000					
	1984	69,410,000		135,134,000					
	1985	79,523,000		142,695,000					
10. Estimated total number of fish landed as percent of total fish caught	1979	39,711,000	(39%)	58,428,000	(36%)	271,000	(63%)	1,556,900	(58%)
	1980	33,964,000	(44%)	63,294,000	(41%)				
	1981	27,384,000	(50)	46,076,000	(35%)				
	1982	33,474,000	(44%)	45,339,000	(29%)				
	1983	42,543,000	(55%)	23,672,000	(22%)				
	1984	32,184,000	(46%)	39,485,000	(29%)				
	1985	37,930,000	(48%)	33,518,000	(23%)				
11. Est. total wt. (lb.) of fish landed	1979	48,572,000		71,841,000		272,048		1,910,065	
	1980	62,734,000		117,666,000					
	1981	52,216,000		93,810,000					
	1982	46,197,000		87,968,000					
	1983	60,679,000		33,583,000					
	1984	78,858,000		55,505,000					
	1985	74,683,000		56,622,000					

Continued on next page.

boats, while Gulf visitors apparently preferred to fish from man-made structures (bridges, piers, and jetties) and private boats. Both resident and visiting anglers in Puerto Rico and the U.S.V.I. preferred to fish from beaches, banks, and private boats in 1979.

Angler success, if measured by average number of fish caught per trip was greatest for anglers fishing from private boats in the South Atlantic (5.6 fish per trip), Gulf of Mexico (8.7 fish per trip) and Puerto Rico (3.8 fish per trip). Fishing from beaches and banks in the Virgin Islands yielded the highest local catch rate of 5.7 fish per trip in 1979.

In 1985, South Atlantic anglers were able to put the greatest weight of fish in their coolers by fishing from party or charter boats more than 3 miles from shore during March and April. In the Gulf, the same result was achieved by fishing from private boats more than 3 miles from shore during July and Au-

Table 2.—Continued.

Characteristic	South Atlantic	Gulf	Caribbean	
			U.S.V.I	Puerto Rico
12. Percent total wt. fish landed by area caught (1985)				
Bays, sounds, rivers	13%	19%	1%	9%
Ocean <3 mi. from shore	29%	33%	34%	38%
Ocean >3 mi. from shore	58%	48%	65%	43%
Unknown	0%	0%	0%	0%
13. Percent fishing trips by method (1985)	Total trips = 19,840,000	Total trips = 24,227,000	Total trips = 39,400	Total trips = 639,200
Bridge, pier, jetty	25%	27%	7%	24%
Beach or bank	24%	18%	32%	43%
Private or rental boat	33%	48%	50%	26%
Charter or party boat	18%	7%	11%	7%
14. Percent of fishing trips by mode for coastal state visitors and residents (1985)	Vis./Res.	Vis./Res.	Vis./Res.	Vis./Res.
Bridge, pier, jetty	24 25	33 25	0 8	15 24
Beach or bank	27 23	14 19	5 35	14 43
Private or rental boat	14 41	43 50	76 47	38 26
Charter or party boat	35 11	11 6	19 10	3 7
15. Estimated economic impacts (1985)[5]				
Sales	$2,038,691,000	$1,354,585,000	Data not avail.	Data not avail.
Value added	908,538,000	619,085,000		
Wages and salaries	402,225,001	270,656,000		
Employment (person-years)	25,126	17,120		
Annual capital expenditures	62,064,000	55,212,000		

[1]Unless otherwise noted data sources include the 1985 NMFS National Marine Recreational Fisheries Statistics Survey, Atlantic and Gulf Coasts, and the 1979 National Marine Recreational Fisheries Statistics Survey, Caribbean Region. Unless otherwise noted, data are for calendar year 1985 for South Atlantic and Gulf and calendar year 1979 for Caribbean.
[2]Data from Boating Statistics 1985. U.S. Dep. Transp., U.S. Coast Guard, 1986. Wash., D.C., 34 p.
[3]O'Hara (1985).
[4]"Other fishes" is a species grouping used in the National MRF Statistics Survey which includes 130 assorted unrelated species that individually are "rarely" caught and for which there are insufficient observations to generate a reliable estimate.
[5]Estimates generated by authors using data in: Sport Fishing Institute (1983), p. IX.

gust. Based on 1979 statistics, Caribbean anglers landed the most pounds of fish by fishing from private boats less than 3 miles from shore during January and February in Puerto Rico or by fishing from private boats more than 3 miles from shore in May and June in the U.S.V.I.

Several other aspects of marine recreational fishing patterns in the southeastern U.S. warrant mentioning. First, saltwater sport fishing tournaments are becoming increasingly importnat. According to one source, almost 400 tournaments were held in the region in 1986 (Table 2, item 5) (O'Hara, 1986). In addition to increased numbers, tournaments have diversified beyond the classic high-stakes billfish kill competitions to include tournaments appealing to both males and females of all ages, skill levels, and target species preferences. Some tournaments like the Scott's Hill Mackerel Tournament (N.C.) are being used to help develop fisheries for species that have been historically snubbed by anglers as "trash fish" (e.g., amberjack, *Seriola* spp.; triggerfish, *Balistes* spp.; Atlantic spadefish, *Chaetodipterus faber*; sharks, and sea catfish, *Arridae*). Also, in many cases, tournaments such as the Pompano Beach Fishing Rodeo (Fla.) are being used as fund raisers for locally important fishery development projects, tourist attractions, or as a means to promote conservation practices among anglers.

Second, in a similar fashion, it is important to note the expanding role of artificial reef development in the southeast. The region is unsurpassed in terms of the number and diversity of artificial reefs built to enhance fisheries habitat and saltwater angling. Including an estimated 3,700 offshore structures, the Gulf probably has in excess of 4,000 artificial reefs. Based on a recent survey by Witzig[3], more than 37 percent of all 1984 saltwater fishing trips by Louisiana coastal residents and 28 percent of those made by Texas residents were made to sites within 200 feet of an offshore structure. Significant positive differences in catch rates and composition existed for many trips made around offshore structures. While not measured in the survey, the positive impacts of non-oil and gas related artificial reefs on saltwater sport fishing and tourism in the South Atlantic, Gulf and Caribbean are well recognized, and are being enhanced through artificial reef development programs supported by every southeastern coastal state, Puerto Rico, the U.S.V.I., and the NMFS Southeast Regional Office.

[3]Witzig, J. F., 1985. Rig fishing in the Gulf of Mexico - 1984 marine recreational fishing survey results. Unpubl. rep., Natl. Mar. Fish. Serv., Wash., D.C., 4 p.

Catch

In 1985, average catch rates and total catches in the South Atlantic and Gulf were not significantly different from the 1979-84 averages. It is, however, interesting to look at several aspects of recreational catches in the southeast in 1985.

Of the 79.5 million fish caught in the South Atlantic in 1985, 37.9 million (48 percent) were landed, 19.4 million (24 percent) were used for bait, discarded dead, or filleted at sea, and 22.2 million (28 percent) were released alive. The

37.9 million fish that were landed weighed approximately 74.7 million pounds.

Interesting differences exist between the species anglers say they target and what they actually land (Table 2, items 6, 7, and 8). In 1985, over 56 percent of South Atlantic anglers didn't fish for a specific species of fish. Of the more selective anglers, spotted seatrout, *Cynoscion nebulosus*; bluefish, *Pomatomus saltatrix*; red drum, *Sciaenops ocellatus*; other fishes (a broad 130-species category including Atlantic spadefish, sailfish, *Istiophorus platypterus*; and marlin, *Istiophoridae*), and king mackerel, *Scomberomorus cavalla*, commanded the most attention. Five species (spot, *Leiostomus xanthurus*; black sea bass, *Centropristis striata*; bluefish; Atlantic croaker, *Micropogonias undulatus*; and mullet, *Mugil* spp.) accounted for 51 percent of all fish landed. All five of these species are found relatively close to shore and are easily available to the bulk of South Atlantic anglers.

Catch and catch disposition patterns in the Gulf in 1985 yielded a slightly different pattern. Of the 142.7 million fish caught, 33.5 million (24 percent) were landed, 44.9 million (31 percent) were either used for bait, discarded dead, or filleted at sea, and 64.2 million (45 percent) were released alive. Landed fish weighed approximately 56.6 million pounds.

As in the South Atlantic, a large proportion (58 percent) of Gulf anglers had no species preference, and of those that did, spotted seatrout, red drum, and "other fishes" (Atlantic spadefish, sailfish, marlins, etc.) again scored high marks. Interestingly, only three of the five most frequently caught fish in the Gulf showed up in the five most frequently landed category compared to four out of five in the South Atlantic. The smaller proportion of Gulf fish that are landed (24 vs. 48 percent in the South Atlantic), is largely explained by the large numbers of sea catfishes, pinfish, *Lagodon rhomboides*; croaker, mullet, and spotted seatrout that are caught but not landed. These fish were either viewed as undesirable or were not landed because of regulatory (size/bag limits) or self-imposed conservation limitations. As in the South Atlantic, five species of fish accounted for over 50 percent of the total number of landed fish.

The Caribbean has yet a different picture. Based on 1979 data, it appears that a much higher percentage of recreationally caught fish is landed in Puerto Rico (58 percent) and the U.S. Virgin Islands (63 percent). There is also a marked difference between what is sought and caught. With the exception of mackerels/tuna in the Virgin Islands and herrings in Puerto Rico, none of the species targeted show up in the top five species caught. Similarly, only two of the top five fish landed in the Virgin Islands and one in Puerto Rico are included among the top five fish sought.

A point worth noting is that in 1979, 85 percent of Puerto Rican anglers and 50 percent of U.S.V.I. anglers reported that they had no target species preferences. This lack of selectivity, taken in conjunction with the large percentage of fish landed, reflects the extent of intermixing between recreational and subsistence fishermen in Puerto Rico and in the Virgin Islands. Local fishery officers report that it is difficult to differentiate between nonselective recreational anglers and subsistence fishermen when conducting field surveys. This subsistence orientation also partially explains the high proportion of fish that are caught and landed.

Analysis of catch and catch disposition patterns in the southeastern United States has prompted personnel in the NMFS Southeast Regional Office to initiate several noteworthy projects. First, given the increasing magnitude of recreational fishing participation and catch and the growing number of fisheries that have come under Federal management and regulation, expanded efforts were initiated in 1987 to better inform anglers of Federal fishing regulations and to encourage their support and compliance.

Second, because of the large numbers of recreationally caught fish that are released alive, a high quality video and printed brochure are being developed to inform anglers of proper catch and release techniques. This will encourage anglers to use catch and release conservation practices and help increase the survival rate for released fish.

Third, an expanded program is being implemented to help anglers make better use of their catches. Based on several surveys and studies (KCA, 1983; Johnson and Griffith, 1985), it is apparent that many fish are not landed and used by anglers because they are perceived to be undesirable or unusable. In many instances these perceptions are based on local biases and incorrect or incomplete information. The NMFS Southeast Region launched a regionwide research and education program in 1983 to identify and correct these misconceptions. Thus far, basic research identifying southeastern species with MRF development potential has been completed, education materials have been developed (brochures, posters, underutilized species cookbook, tournament guides, etc.), and an educational program initiated. A more expansive education effort and a media "blitz" are being planned for 1988.

Collectively, these three initiatives, in conjunction with other state and Federal fisheries management programs, should help reduce fishing pressure on currently stressed species, reduce waste, help anglers more fully utilize available fishery resources, and help maintain angler satisfaction with their sport fishing experiences.

Economic Significance

Marine recreational fishing the U.S. southeast is indeed an activity of economic significance to the region. Not only are saltwater anglers visiting the productive waters of the region in growing numbers, but they are also spending increasing amounts of money. According to a study conducted by the Sport Fishing Institute (1983), marine recreational fishermen spent nearly $2.2 billion in the Gulf and South Atlantic areas in 1980 on fishing tackle, boats, motors, trailers, marine services, charter and headboat trips, boat fuel, boat insurance, bait, food, lodging, transportation, and other miscellaneous items. These direct sales resulted in over $986 million in indirect economic impacts as money was respent throughout the region. Furthermore, direct sales stimulated nearly $88 million

worth of capital investment and directly supported nearly 36,000 person-years of employment representing $381.7 million in wages and salaries. From a national perspective, the Gulf and South Atlantic areas accounted for over 55 percent of all retail sales associated with marine recreational fishing in the United States in 1980 (Sport Fishing Institute, 1983). While economic data are not currently available for the Caribbean area, it is clear that marine recreational fishing is an integral and important part of the area's economically significant tourist industry.

To estimate the expenditures and associated economic impacts resulting from marine recreational fishing the southeast in 1985, the 1980 estimates were adjusted by an annual real growth factor of 3.4 percent and a MRF composite Consumer Price Index factor of 1.3059 (SFI, 1987). This annual real growth factor of 3.4 percent was reported by Sport Fishing Institute (1983) for the period 1972-80 and was used for this estimate even though the recession that occurred in the United States in the early 1980's probably reduced the rate of real growth in MRF expenditures. However, based on the estimate, direct MRF expenditures in the South Atlantic and Gulf could have grown from $2.2 billion in 1980 to nearly $3.4 billion in 1985. Associated estimated increases in value added, employment, wages and salaries, and capital expenditures are presented in Table 2, item 15.

There is still considerable discussion and debate regarding the magnitude of MRF related economic impacts and proper methods for estimating those impacts and values in the southeast. For example, a study done by Bell (1982) of the University of Florida concluded that in 1980, resident and tourist marine recreational fishermen spent $1.87 billion in Florida on fishing-related, nondurable goods at the retail level. This estimate appears out of proportion with the Sport Fishing Institute's $2.2 billion estimate of direct MRF-related expenditures for the entire South Atlantic and Gulf of Mexico area in 1980. The range of "values" that have resulted from these various economic studies is perhaps equalled only by the number of estimation methods that have been used. Appropriate methods for estimating economic impacts and value of marine recreational fishing need to be developed and applied consistently.

Discussion

The importance of marine recreational fisheries in the southeastern United States is receiving growing recognition among local, state, and Federal resource managers. In October 1983, the NMFS Southeast Regional Office and Southeast Fisheries Center implemented an MRF Program Development Plan (PDP) to promote the stability and growth of marine recreational fisheries in the region. In addition to briefly describing MRF in the region, the PDP outlines a long-term program directed at resolving the following seven major impediments:

1) Lack of comprehensive and reliable MRF data base,

2) Lack of organization unity in the MRF community,

3) Need for more effective fishery habitat protection and enhancement,

4) Need to resolve MRF-related fishery allocation, conservation, and management problems,

5) Need to improve access to coastal waters and fishery resources,

6) Need for improved communication and relations with MRF constituents and improved user information, and

7) Need for improved coordination between MRF-related government programs.

With the assistance and cooperation of the states, universities, Sea Grant programs and the marine recreational fishing community, significant progress is being made in resolving these problems. Ultimately, the stability and growth of marine recreational fisheries in the southeastern United States will be secured.

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Marine Recreational Fishing and Associated State-Federal Research in California, Hawaii, and the Pacific Island Territories

MARK HELVEY, STEPHEN J. CROOKE, AND PETER A. MILONE

Introduction

Increases in population, per capita income, travel activity, and leisure time will continue to fuel participation in outdoor recreation over the next 25 years (Clawson, 1985). Whether this trend remains balanced among current recreational outlets or shifts to others can only be speculated. In the Southwest Region of the National Marine Fisheries Service (NMFS), which includes all of California, Hawaii, and Pacific Island territories, there are indications that marine recreational fishing will continue to grow in popularity. These include greater recreational use of small harbors and bays (Johnson and Metzger, 1983), demand for more boat slips and berths (Morash, 1986), and continued interest in quality fishing and fishery products (Thompson, 1984; Braekkan, 1985).

In anticipation of this growth, there will be an even greater need to manage fishery resources prudently so that all commerical and recreational fishermen can partake equitably without overharvest of the resource. In particular, state and Federal fishery managers will need to continue monitoring the impact of fishing as well as continue to investigate the biological processes affecting the availability of marine resources. This paper provides an overview of marine recreational fishing within the NMFS Southwest Region and briefly outlines a few of the ongoing and future state-federal research and assistance programs addressing recreational fishing.

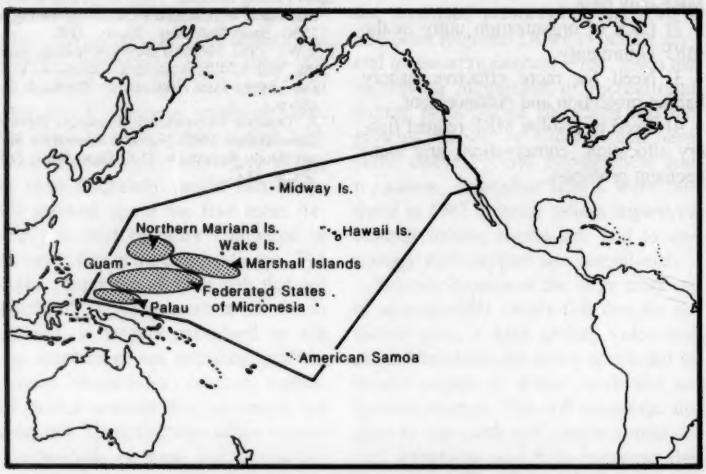

Figure 1.—The NMFS Southwest Region.

Background Information

The responsibilities of the NMFS Southwest Region for living marine resources encompass over 1.3 million square miles of the Pacific Ocean off California, Hawaii, the U.S. territories of Guam and American Samoa, the Commonwealth of the Northern Mariana Islands, the U.S. possessions, and to a lesser extent, the freely associated states of the Marshall Islands, the Federated States of Micronesia, and Palau (Fig. 1).

Three broad climatic regimes regulate the diversity of fishes inhabiting these waters. The cold and productive subarctic waters of northern and central California support large populations of demersal and anadromous fishes of northern affinity such as salmon (Salmonidae), rockfish (Scorpaenidae), and greenlings (Hexagrammidae). The temperate waters of southern California from Pt. Conception to the Mexican border (known as the Southern California Bight), support many demersal fishes of northern affinity such as rockfish plus reef-oriented and pelagic species of southern affinity such as sea basses (Serranidae), tunas (Scombridae), and jacks (Carangidae). Finally,

Mark Helvey is with the Southwest Regional Office, National Marine Fisheries Service, NOAA, 300 S. Ferry St., Terminal Island, CA 90731. Stephen J. Crooke is with the California Department of Fish and Game, 245 W. Broadway, Long Beach, CA 90802. Peter A. Milone is with the Western Pacific Program Office, Southwest Region, NMFS, NOAA, 2570 Dole Street, Honolulu, HI 96822.

the tropical waters of the central and western Pacific islands support a wide diversity of pelagic and reef fishes including marlins (Istiophoridae), tunas, groupers (Serranidae), snappers (Lutjanidae), dolphinfishes (Coryphaenidae), and goatfishes (Mullidae).

Participation, Effort, and Catch

California

The NMFS-supported Marine Recreational Fisheries Statistics Survey (MRFSS) originated on the Pacific Coast in 1979. The MRFSS provides a database for estimating sportfishing impact on marine resources and is comprised of a telephone survey to estimate total effort for each coastal county and field interviews to determine species composition and weights. All salmon boat anglers are excluded from the survey as each state estimates its own salmon catch.

Data compiled from the California MRFSS for 1981-85 (NMFS, 1984, 1985, 1986) indicate that there are nearly double the number of anglers fishing in southern California marine waters as there are in the central and northern part of the state combined (Fig. 2A). Higher coastal population, greater species diversity and moderate weather conditions in southern California account primarily for this difference. Anglers residing in coastal counties make up about 75 percent of all fishermen in the state (Fig. 2A). The average number of trips taken by southern California coastal participants is approximately double that of central and northern participants, but the percentage of total trips by these anglers is about equal (Fig. 2B).

The percent of fishing effort from man-made structures (e.g., piers, jetties) and private/rental boats (i.e., boats individually owned or rented) is almost the same throughout California (Fig. 3A). The private/rental boat mode is the most popular, accounting for more than 35 percent of all fishing trips statewide (Fig. 3A). Fewest fishing trips occur on commercial passenger fishing vessels in central and northern California while fewest trips occur along the beaches in southern California.

The number of fish landed[1] by recreational anglers in southern California from 1981-85 averaged 14.2 million fish weighing 20.4 million pounds, compared with 10.5 million fish weighing 11.8 million pounds in central and northern California. The 74 percent greater weight of fish landed in southern California than in central and northern California is due primarily to the availability of larger species such as albacore, *Thunnus alalunga;* bonito, *Sarda chiliensis,* and other pelagic species.

While landing figures are not available by mode, catch by mode can be used to indicate success in different areas. In central and northern California, beach/bank fishing is the most productive because of the high numbers of surfsmelt, *Hypomesus pretiosus,* and northern anchovy, *Engraulis mordax,* caught from the shoreline (Fig. 3B). In contrast, commercial passenger vessels and private rental boats account for 83 percent of the total number of fish caught in southern California.

In southern California, a small proportion of the private boat fishermen account for most of the effort in the billfish fishery. Many of these anglers participate in a tag and release program, and since 1963, have tagged and released over 1,000 striped marlin, *Tetrapturus audax,* and swordfish, *Xiphias gladius,* in the Pacific Cooperative Marine Gamefish Tagging Program. The NMFS's Southwest Fisheries Center in La Jolla, Calif., surpervises this program in cooperation with the International Game Fish Association (IGFA). Participation in this program has increased dramatically in recent years because of a change in emphasis by tournament sponsors from landing to tag-and-release.

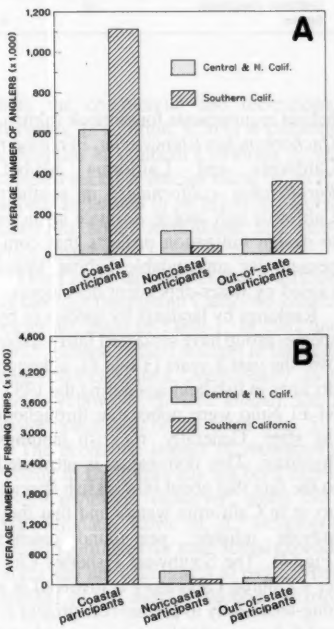

Figure 2.—Distribution by residence of the average number of marine recreational fishermen (A), and average number of fishing trips made by marine recreational fishermen (B) in California waters for 1981-85 based on the MRFSS survey.

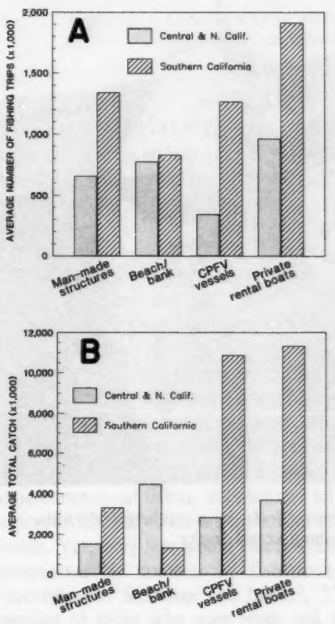

Figure 3.—Distribution by fishing mode of the average number of fishing trips (A), and average total catch (B) made by marine recreational fishermen in California waters for 1981-85 based on the MRFSS survey. CPFV = commercial passenger fishing vessels.

[1]"Fish landed" represents fish retained by fishermen as opposed to "fish caught" which represents all fish landed and all fish released alive or dead due to quota and size regulations.

Figure 4.—A good catch of cowcod, *Sebastes levis*, by a southern California commercial passenger fishing vessel angler.

Table 1.—Rank by landings (numbers of fish) of top ten species and species groups during 1981-85 by California marine recreational fishermen based on the MRFSS survey.

Area and species	1981	1982	1983	1984	1985
Central and Northern California					
Rockfish	1	1	1	2	1
Surfsmelt		2	2	1	2
Northern anchovy	2			3	
Sandabs	3	8	3	7	4
Jacksmelt	4	5	6	8	
White croaker	9	7	8	4	3
Pacific mackerel	6	3	4	5	9
Lingcod	5	4	7	10	5
Barred surfperch	7	9		9	7
Redtail surfperch	8	6	10		10
Shiner surfperch					8
Striped surfperch		10			
Pacific herring	10		5	6	6
Walleye surfperch			9		
Southern California					
Rockfish	1	1	2	1	1
Pacific mackerel	2	2	1	2	2
Pacific bonito	3	5	3	3	7
Barred sandbass	7	3	6	6	3
White croaker	4	4	5	4	5
Kelp bass	5	6	4	5	4
Queenfish	9	8		7	6
Barred surfperch	6	7	8	9	10
Yellowtail			7		
Jacksmelt	8	9	9	8	8
Walleye surfperch	10				
California barracuda		10		10	
California sheephead			10		
Smelts					9

Nonsalmon sport fishermen in central and northern California catch 93 percent of their fish within 3 miles of the coast compared with 81 percent for southern California fishermen. In addition to the convenience of fishing nearshore, coastal waters support many prized sportfish species that utilize estuarine and riverine habitats as spawning and nursery grounds.

Presently, the NMFS and California Department of Fish and Game (CDFG) are supporting several investigations to establish the habitat requirements of larval and juvenile fishes at these locations. Currently, assessments of spawning habitat requirements for chinook salmon, *Onchorhynchus tshawytscha*, in northern California and California halibut, *Paralichthys californicus*, in southern California will enable resource agencies to design mitigation projects that compensate for unavoidable habitat losses caused by water-dependent developers.

Rankings by landings by species or by species group have remained fairly stable over the past 5 years (Table 1), although declines in fish landings during the 1982-84 El Niño were noticeable throughout the state. Generally, rockfish landings dominate. This dominance is attributed to the fact that about 60 rockfish species occur in California waters and that they provide reliable, year-round catches (Fig. 4). The Southwest Fisheries Center's Tiburon Laboratory is involved in a long-term study to predict recruitment of rockfish to catchable size in central and northern California (Lenarz and Moreland[2]) because of their importance to

[2]Lenarz, W. H., and S. Moreland (editors) 1985. Progress report on rockfish recruitment studies at the Tiburon Laboratory. NMFS Southwest Fish. Cent. Admin. Rep. T-85-02, 19 p., Tiburon, Calif.

Table 2.—Annual total expenditures (tackle and bait costs, boat fees, etc., plus travel and lodging costs), net willingness to pay (see text footnote 4), and annual total value for California marine recreational fishing trips, 1981-85.

Mode	Amounts ($1,000) Central and N. Calif.	S. Calif.	Statewide
Annual total expenditures			
Man-made structures	21,451	43,850	65,302
Beach/bank	29,376	31,383	60,759
Commercial passenger fishing vessels	31,794	116,761	148,555
Private/rental boats	44,134	87,673	131,806
Subtotal	126,755	279,667	406,422
Annual net willingness to pay[1]			
Man-made structures	19,742	40,354	60,096
Beach/bank	28,458	30,402	58,860
Commercial passenger fishing vessels	4,816	17,687	22,503
Private/rental boats	26,343	52,332	78,675
Subtotal	219,929	188,748	408,676
Annual total value	346,684	468,415	815,099

[1]The net willingness to pay dollar values are calculated as all or nothing values for each mode; that is, the amount anglers would be willing to pay in order to continue fishing solely in that particular mode. The subtotal for all modes exceeds the sum of the individual modes because it represents the total value of having fishing in any of the four modes rather than having no fishing at all.

Figure 5.—Landing a large yellowtail, *Seriola lalandi*, on a southern California commercial passenger fishing vessel.

both the commercial and recreational fisheries. In addition, CDFG is initiating a program in southern California to age selected rockfish species taken by recreational fishermen in an effort to resolve questions about recruitment and year-class strength.

Other important species that contribute to landings throughout California consistently are listed in Table 1. In 1982 and 1985, salmon ranked seventh in landings based on CDFG data. Occasionally, as in 1983, yellowtail, *Seriola lalandi*, are a major component of the catch (Fig. 5).

The economic impact of recreational fishing in California has not been extensively reviewed. However, using 1981 MRFSS data, Rowe et al.[3] developed per-trip estimates for total actual expenditures and net willingness to pay[4]. When applied to the average number of trips taken from 1981 to 1985, the annual total value for all trips and all modes statewide in 1985 dollars is estimated to be $815 million (Table 2).

Hawaii

Recreational fishermen throughout the mainland United States are generally motivated by their enjoyment of the sport as a pastime. By contrast, fishermen in Hawaii are often motivated by a combination of factors which tend to blur traditional distinctions between recreational and commercial fishermen. In Hawaii, many recreational/subsistence fishermen hold commercial fishing licenses and sell a portion of their catch to supplement income. Yet, very few would characterize themselves as commercial fishermen. According to Skillman and Louie[5], 27 percent of those who own boats sell a portion of their catch but only 3 percent derive more than half of their gross income from fishing. Despite this overlap between commercial and recreational fisheries, the recreational motivation for fishing appears to predominate among most Hawaiian fisherman (Department of Land and Natural Resources[6]).

Surveys of recreational fishing in the Hawaiian Islands are few. The most recently compiled data comes from the National Recreation Survey by the U.S. Department of Interior (1980) which estimated 154,400 Hawaii residents out of a population base of 707,000 engaged in sportfishing in 1980; those fishermen reportedly made 2.74 million trips.

Shoreline fishing is the most popular mode involving 68 percent of all recreational/subsistence fishermen (Hoffman and Yamauchi[7]). These fishermen primarily use pole-and-line to target a wide variety of species including the highly prized uluas or large-sized jacks, *Caranx*

[3]Rowe, R. D., E. R. Morey, A. D. Ross, and W. D. Shaw. 1985. Valuing marine recreational fishing on the Pacific Coast. NMFS Southwest Fish. Cent. Admin. Rep. LJ-85-18C, La Jolla, Calif.

[4]Net willingness to pay or "consumer surplus" represents the monetary value an angler would be willing to pay over and above actual out-of-pocket expenditures to maintain existing fishing opportunities.

[5]Skillman, R. A., and D. K. H. Louie. 1984. Inventory of U.S. vessels in the central and western Pacific. Phase 2: Verification and classification of Hawaiian vessels. NMFS Southwest Fish. Cent. Admin. Rep. H-84-12, Honolulu.

[6]Department of Land and Natural Resources, State of Hawaii. 1980. Hawaii coastal zone fisheries management study, Honolulu.

[7]Hoffman, R. G. and H. Yamauchi. 1973. Impact of recreational fishing expenditures on the state and local economies of Hawaii. Univ. Hawaii, Sea Grant Program Rep. AR-72-02, Honolulu.

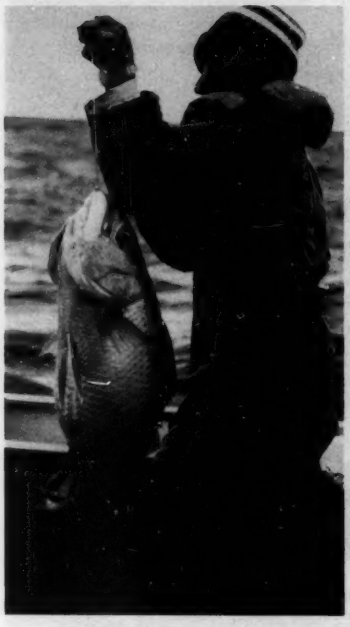

Figure 6.—A 25-pound "onaga" or red snapper, *Etelis carbunculus*, caught by handline off Hawaii in 140 feet of water.

spp., commonly found in turbulent waters near rocky shorelines. Other common gear types include throw nets, gill nets and spears. The State of Hawaii's Division of Aquatic Resources is engaged in efforts to survey shoreline fishery resources and fishermen's participation levels at selective locations throughout the state. This information will be used in developing shoreline "kapu" fishery management programs which involve opening and closing certain areas to fishing activites on a rotating basis.

Offshore recreational fishing is also popular for the estimated 3,500 boat owners (Department of Land and Natural Resources, 1986) in Hawaii who commonly troll for tuna and marlin or handline for deepwater snappers, groupers, and jacks (Fig. 6). These boats are permanently moored or trailered to launch ramps throughout the islands (Department of Land and Natural Resources, 1986). Although most fishing by the recreational "mosquito fleet" occurs on weekends and in the calm summer months, fishing effort does increase when the market demand for certain species is high.

State and Federal support for offshore sportfishing is most visible in the form of fish aggregation devices (FAD's) which are now deployed in waters throughout the state. Early experiments with FAD's by the Southwest Fisheries Center's Honolulu Laboratory (Matsumoto et al., 1981) led to the development of a statewide FAD program which currently numbers 48 buoys. In addition, the State of Hawaii recently established an experimental "trolling alley" comprised of a series of midwater aggregation buoys off the island of Oahu.

Marine recreational fishing generates substantial economic benefits to the State of Hawaii. In 1980, Hawaiian recreational fishermen spent about $38.3 million on fishing vessels, equipment, repairs, moorage, etc. (U.S. Department of Interior, 1980). The value of fishery landings attributable to these fishermen is difficult to determine; nevertheless, the volume in weight of recreational landings is probably large and comparable to Hawaii's commercial catch (Department of Land and Natural Resources, 1986).

Charter boat fishing operates year round out of the main Hawaiian Island ports, with the fleet concentrated primarily on the islands of Oahu and Hawaii. The fleet size was estimated at 119 vessels which produced an estimated 73,780 passenger trips in 1982 (Samples et al.[8]). Total expenditures by patrons on charter boats was estimated at $52.5 million in 1983 (Samples and Shug[9]).

The total fish catch by Hawaii's charter fleet is substantial and constituted 2.2 million pounds or about 15 percent of the State's reported commercial catch in 1982. The charter boat catch is particularly important for certain species such as the blue marlin, *Makaira nigricans* (Fig. 7). For example, the estimated blue marlin catch by the charter fleet in 1982 was 180 percent higher than the reported commercial catch of blue marlin[9].

This reputation for big-game marlin and tuna fishing is an important adjunct to the State's tourism industry and has contributed to the growing number of fishing tournaments held in Hawaii, the most famous being the Hawaiian International Billfish Tournament (HIBT) held each August in Kailua-Kona. Six of 13 IGFA records held for Pacific blue marlin catches are from Hawaii (IGFA, 1986). Interestingly, the 1986 HIBT inaugurated a tag and release program by offering teams bonus points for tagging fish (Gaffney[10]) and it appears that this will be a common feature of this and other Pacific tournaments.

Pacific Island Territories

The differentiation between commercial and recreational/subsistence fishermen is even less clear in the distant Pacific island territories of the United States. Income levels are generally lower than those in Hawaii, and thus fishing assumes a greater importance because of its subsistence and income producing capability. Although each island area has a small but discrete full-time commercial fishery, the majority of offshore fishermen sell their catch and can be considered part-time recreational and quasi-commercial.

Precise information on sportfishing participation and catch in the Pacific island territories is sparse. Nevertheless, the fishery agencies in Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands are presently engaged in a number of fishery surveys in an effort to generate comprehensive data on the extent of fishery participation, catch, and effort in nearshore and offshore waters. Similar survey programs are planned for the Federated States of Micronesia, Palau, and the Marshall Islands.

Reefwalking and shoreline fishing

[8]Samples, K. C., J. N. Kusakabe, and J. T. Sproul. 1984. A description and economic appraisal of charter boat fishing in Hawaii. NMFS Southwest Fish. Cent. Admin. Rep. H-84-6C, 130 p., Honolulu.

[9]Samples, K. C., and D. M. Schug. 1985. Charter fishing patrons in Hawaii: A study of their demographics, motivations, expenditures and fishing values. NMFS Southwest Fish. Cent. Admin. Rep. H-85-8C, 95 p., Honolulu.

[10]Gaffney, R. 1986. "Finally a grander!" Hawaii Fish. News (Honolulu), Sept. 1986, p. 14.

with pole-and-line, nets, or spears are methods commonly used by island residents in pursuit of subsistence fisheries. The majority of fishing vessels in the islands are small, trailerable vessels 18-25 feet long. Most of these vessels are used to troll for tunas, marlin, dolphinfish, and wahoo, *Acanthocybium solandri*, often with effort directed around FAD's which are widely used in the Pacific territories. Handline fishing for deepwater snappers and groupers also is common.

A small fleet of charter sportfishing vessels has begun to emerge with the growth in tourism taking place in the U.S. Pacific islands. Presently, six vessels in American Samoa and ten vessels in Guam are available for hire for sportfishing (WPFMC[11]). Marlin, tunas, and dolphinfish are the principal target species. There also has been an emergence of fishing tournaments in recent years as a means of promoting sport fishing opportunities in each respective island.

Future Direction of State-Federal Programs

A joint NMFS and CDFG task force formed in spring 1986 portrayed the future of California recreational fisheries to 1996 as a period that many associated with the sport would like to avoid. For instance, an increase in Mexican domestic fishing along Baja California was identified as an impediment to the availability of migratory species such as white seabass, *Atractoscion nobilis*; yellowtail, and California barracuda, *Sphyraena argentea*, to California fishermen. A continued decline was predicted for rockfish and lingcod stocks in central and northern California as intense fishing pressure from the commercial and recreational sectors continued. To circumvent these events, both agencies developed, with the participation of private citizens actively involved in recreational fishing, a strategic plan designed to serve as a framework for directing and coordinating their recreational fishing programs through 1996.

The timing of this plan is opportune because of the increased emphasis on recreational fishing by both agencies. For instance, with support from a NMFS Saltonstall-Kennedy (S-K) grant, the National Coalition for Marine Conservation-Pacific Region is currently evaluating the relationship between angler expenditures and fish species abundance in California for the NMFS Southwest Regional Office. With similar funds, the University of California Sea Grant Marine Advisory Program is developing strategies for increasing the use of underutilized sportfish. Also, the Southwest Fisheries Center's La Jolla Laboratory recently sponsored a supplemental economic survey of recreational fishing from Monterey northward in conjunction with the MRFSS. The CDFG recently initiated a sportfish age composition study and an egg and larval population study, both supported by Wallop-Breaux funds[12]. Further, CDFG has accelerated its efforts to install artificial reefs in southern California.

In the Pacific islands, emphasis is being placed on obtaining accurate and timely estimates of sportfishing catch and effort. Future research is intended to generate comprehensive information on the participation, catch, and value associated with recreational fisheries. There are plans for further refinement of data originally collected in the Pacific during the 1981 MRFSS and the development of new survey techniques to capture needed fishery information on the unreported

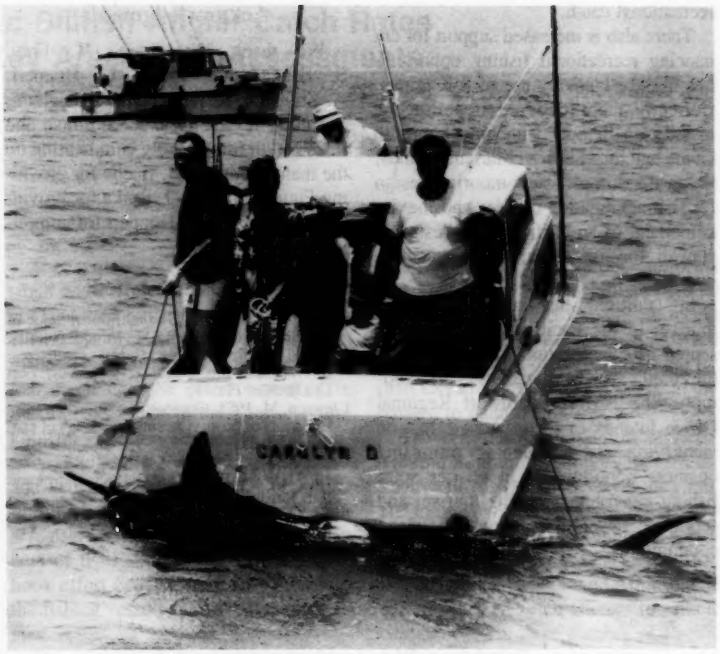

Figure 7.—A blue marlin, *Makaira nigricans*, caught by recreational fishermen off the Hawaiian Islands.

[11]WPFMC. 1986. Fishery management plan for the pelagic fisheries of the western Pacific region. West. Pac. Fish. Manage. Counc., Honolulu.

[12]The Wallop-Breaux fund, formerly known as the Dingell-Johnson fund, is derived from Federal excise taxes on fishing tackle, outboard motors, and recreational motor boat fuel and on import duties on sport fishing equipment, pleasure craft, and yachts. The funds are provided to the states and territories for sport fishing related projects.

recreational catch.

There also is increased support for enhancing recreational fishing opportunities in the islands by use of S-K grants. Currently, these funds are supporting the installation of boat launching ramps in Guam and the Northern Mariana Islands, the evaluation of a new mooring design for fish aggregation devices and the development of an artificial reef design in Hawaii for use in turbulent nearshore waters.

In addition, the rapid growth of tourism in the Pacific islands has presented new opportunities for expanding the charter sportfishing industry. Accordingly, the NMFS Southwest Regional Office intends to focus more effort on identifying and developing promising business opportunities in charter sport fishing consistent with the tourism and economic development goals of island communities.

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Pacific Billfish Angler Catch Rates for Key Area Stock Assessments

JAMES L. SQUIRE

ABSTRACT—The Pacific Billfish Angler Survey was initiated in 1969 to measure the trend of angler CPUE annually. Survey respondents (1969-84) have reported 145,661 angler days catching 59,460 billfish, resulting in an average CPUE of 0.41 fish/day or 2.45 days of fishing per billfish. Annual totals of catch, effort, and resulting CPUE are given for many of the important recreational billfish fishing areas. A comparison of CPUE trends between the commercial longline and the recreational angler is made for the area about the southern tip of Baja California where high CPUE rates are common to both fisheries. The correlation between recreational and commercial CPUE is reasonable ($Y_2 = 0.82$), and the recreational angler CPUE is negatively affected by the nearby commercial longline fishery.

Introduction

The catch per unit effort (CPUE) or other statistical measures of fishing effort and success are not well known for most Pacific big-game fisheries for billfishes (and also tunas). Nevertheless, assessments of the stocks involved concern both anglers and fishery managers confronted with interactions arising from commercial and recreational interests in these fisheries.

Fisheries agencies have long attempted to obtain data on billfish catch, effort, and biology from recreational fisheries. Data have been obtained from tournaments, voluntary logbooks programs, club records, observations of charterboat catches, individual angler records, and from special government monitoring programs. Some of this sampling has been successful, but in most cases quality of the statistics or sampling bias has been a problem (Abramson, 1963; Calhoun, 1950).

The sport fishery consists of many small and mobile units that may or may not land their billfish catches at locations where the record of the landing was made. The total annual recreational billfish catch and the effort expended in making this catch in the Pacific is unknown. The commercial longline, harpoon, and gillnet fleets of Japan, Korea, and Taiwan account for the major portion of billfish taken in the Pacific, and extensive data on landings in weight and numbers of fish, and locations of catch and hook effort expended are maintained by the fishing vessels for government agencies.

The purpose of this paper is to show that catch rates derived from localized recreational fisheries can be used to monitor stocks that are distributed widely and also commercially exploited. The center of distribution of such stocks, however, must be near the recreational fishery. Catch rates of billfish from recreational fisheries will be described and then compared with those from commercial fisheries.

The Angler Survey

Early west coast marine sport fishery surveys to determine total catch were conducted by the U.S. Fish and Wildlife Service through contract to the U.S. Department of Commerce, Census Bureau (Clark, 1960). They were inaccurate relative to billfish catch, as indicated by comparisons of the number of billfish aught off southern California with records from various billfish clubs. The Pacific Billfish Angler Survey was initiated to obtain a better measure of both catch and angler effort from California and from other major billfish fishing areas in the Pacific Ocean. In recent years, angler response has been received from recreational fishing areas in the Indian Ocean and the survey has been expanded to include this area.

The U.S. Fish and Wildlife Service's Tiburon Marine Laboratory began the Pacific Billfish Angler Survey in 1969, and the survey was later transferred to the U.S. Department of Commerce's National Marine Fisheries Service (NMFS) in the National Oceanic and Atmospheric Administration. In an attempt to sample economically a large number of Pacific billfish anglers, the postcard type survey method was adopted. G. B. Talbot was the original designer of the postcard-type Pacific Billfish Angler Survey.

The postcard survey method of obtaining recreational fishery data has certain problems as reviewed by Abramson (1963) and Calhoun (1950). One problem is that it may be difficult for a fisherman to remember precisely the catch from the previous year. However, since the average billfish angler does not participate in the sport frequently, and since his catch is small and billfish are "trophy fish," his recall should be better than might be expected. The survey postcard format has changed considerably since 1969 (Squire, 1974). It has been simplified to encourage accurate and complete response (Fig. 1). Anglers are requested to give an honest answer and are told that information on zero catches was important. Despite its simple format, billfish anglers frequently make mistakes in completing the survey form.

The Pacific Billfish Angler Survey form is mailed annually with the NMFS Southwest Fisheries Center's *Billfish Newsletter*. The newsletter and angler survey form are sent to all anglers who

James L. Squire is with the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, 8604 La Jolla Shores Drive, La Jolla, CA 92038.

Figure 1.—Pacific Billfish Angler Survey form.

PACIFIC INTERNATIONAL BILLFISH ANGLING SURVEY
FOR CALENDAR YEAR 1983

NOAA FORM 88-16 — National Marine Fisheries Service — In cooperation with the International Game Fish Association — OMB NO. 0684-0020

LOCATION	HOW MANY DAYS YOU FISHED FOR BILLFISH BY QUARTER (1983 ONLY)				HOW MANY BILLFISH CAUGHT BY QUARTER (1983 ONLY)															
					BLUE MARLIN				BLACK MARLIN				STRIPED MARLIN				SAILFISH*			
	1 JAN MAR	2 APR JUN	3 JUL SEPT	4 OCT DEC	1 JAN MAR	2 APR JUN	3 JUL SEPT	4 OCT DEC	1 JAN MAR	2 APR JUN	3 JUL SEPT	4 OCT DEC	1 JAN MAR	2 APR JUN	3 JUL SEPT	4 OCT DEC	1 JAN MAR	2 APR JUN	3 JUL SEPT	4 OCT DEC
SOUTHERN CALIF.																				
BAJA CALIFORNIA																				
GUAYMAS																				
MAZATLAN																				
SAN BLAS																				
MANZANILLO																				
ACAPULCO																				
GUATEMALA																				
COSTA RICA																				
PANAMA																				
ECUADOR																				
PERU																				
HAWAII																				
TAHITI																				
SAMOA																				
GUAM																				
NEW ZEALAND																				
NEW GUINEA																				
AUSTRALIA																				
MALAYSIA																				
JAPAN																				
THAILAND																				
OTHER —																				

*If Shortbill Spearfish indicate by **

Please Fill This Out

NAME _____

STREET ADDRESS: _____ CITY/TOWN: _____

COUNTRY/STATE: _____ ZIP OR MAILING CODE: _____

have either tagged and released billfish, or who have returned an angler survey form for the preceding year. Billfish angler survey forms are distributed during the spring months of the year following the year surveyed. Survey forms are collected for the preceding surveyed year through September. The forms are coded and the catch and effort data are placed in the SWFC computer facility, and are analyzed to determine the catch rates of the various fishing areas in the Pacific.

Estimates of catch and effort were made annually for the total Pacific and for specific fishing areas. Approximate fishing days reported by the billfish angler (f) are summed and divided into the total billfish catch reported (C):

$$\frac{C}{f} = \text{CPUE (catch per angler day).}$$

Also, to determine the average amount of effort required by an angler to catch a billfish is calculated:

$$\frac{f}{C} = \text{EPUC (days fishing per billfish).}$$

Additional analyses are made for each species and major fishing area using approximate fishing effort and catch by species.

Angler response to the survey has been high for southern California. Analysis indicates that at least 33 percent of the anglers catching striped marlin have reported. This estimate is based on the number of striped marlin reported by respondents compared to the total annual striped marlin catch off southern California as reported by the big-game angling clubs. Response level is also high for fishing off Baja California Sur, Mex. and around the Hawaiian Islands, but less so for other ports along the west coast of Mexico, Central and South America, and many other important billfish fishing areas in the Pacific. Anglers have responded with survey cards from 35 different fishing areas in the Pacific. The distribution of the fishing locations is shown in Figure 2.

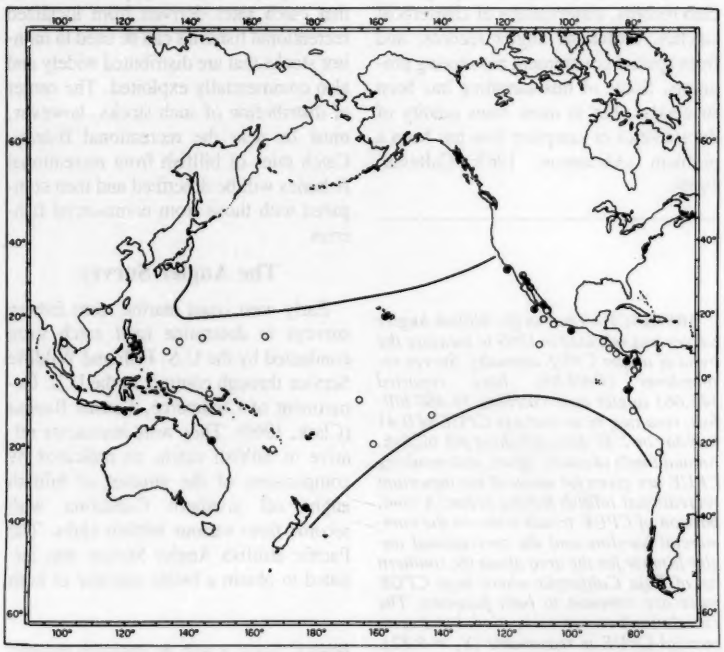

Figure 2.—Locations of billfish angler effort as indicated by survey response. Locations with 1,000 or more angler-days reported are indicated by a circle.

Table 1.—Angler catch rates for the total Pacific Ocean, 1969-83, all billfish species.

Year	Effort (in angler days)	Catch	
		No. of fish	Fish per day
1969	6,481	3,502	0.54
1970	6,569	3,779	0.58
1971	5,622	3,449	0.61
1972	6,899	3,511	0.51
1973	4,788	1,882	0.39
1974	9,635	3,475	0.36
1975	7,305	2,761	0.38
1976	8,591	2,918	0.34
1977	11,125	3,953	0.36
1978	14,453	3,906	0.27
1979	12,058	3,786	0.31
1980	14,100	5,506	0.39
1981	11,075	4,555	0.41
1982	8,782	4,418	0.50
1983	9,070	4,017	0.44
1984	9,108	4,024	0.41
Total	145,661	59,460	

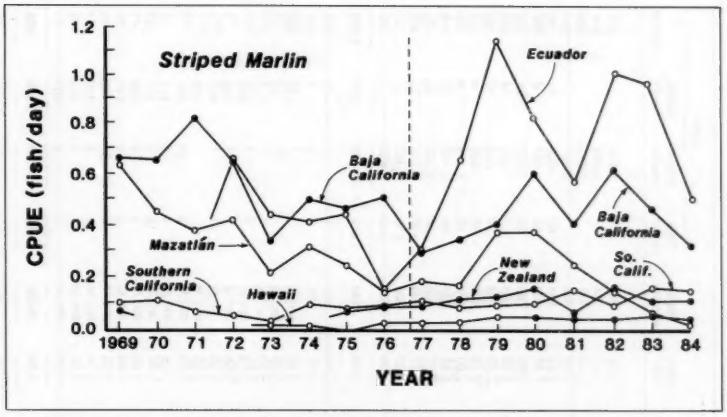

Figure 3.—Catch rates for striped marlin in areas having greater than 2,000 angler days.

Results of the Survey

About 80 percent of the survey cards sent with the SWFC's annual *Billfish Newsletter* were returned. The mailing list for the *Billfish Newsletter* is composed of anglers who have tagged and released billfish or who have participated in previous angler surveys. Some of the anglers who had not fished for billfish during the previous year return their cards so that they can remain on the newsletter mailing list. The combined totals of the catch and effort sample for billfish fishing in the Pacific Ocean for the period 1969-84 is 145,661 angler days (average 9,103 days/year) reporting a catch of 59,460 billfish (all species combined). This is a CPUE of about 0.41 fish per day or 2.45 days per billfish. The highest CPUE, 0.58 fish/day, was recorded in 1970, and the lowest, 0.27 fish/day, was recorded in 1979.

The annual totals of catch, effort, and CPUE are given by year in Table 1. For fishing areas having 1,000 angler days reported, the angler effort, catch by species, and CPUE are given for 1969-83 in Table 2. These areas are southern California (U.S.); Baja California Sur, Guaymas/Pta. Penasco/Kino, Mazatlán, and Acapulco/Zihuatanejo/Ixtapa (Mex.); Australia; Hawaiian Islands; Panama; Ecuador; Costa Rica; and New Zealand. Statistics for locations having a resident level of less than 1,000 angler days are summarized in Table 3.

Striped Marlin

Some of the more productive recreational fishing grounds for striped marlin, *Tetrapturus audax*, in the Pacific Ocean are the areas around the southern tip of Baja California and off the coast of Ecuador. These waters are also fished for blue marlin, *Makaira nigricans*; black marlin, *M. indica*; and sailfish, *Istiophorus platypterus*. A commercial longline fishery targets on striped marlin and swordfish, *Xiphias gladius*; off Baja California Sur near the recreational fishery area. This commercial fishery has produced some of the highest catch rates for striped marlin recorded in the Pacific or Indian Oceans.

Striped marlin catch rates for recreational fisheries off Baja California Sur and Mazatlán, Mex. and off Ecuador, New Zealand, southern California, and the Hawaiian Islands are shown in Figure 3. These areas had effort rates greater than 2,000 angler days during 1969-83.

The recreational fishing area around the southern tip of Baja California Sur is located near a center of high striped marlin availability in the northeast Pacific, an area that accounts for most of the recreational catch of striped marlin in the eastern Pacific. For that reason, changes in catch rate in this area are of interest to recreational anglers, and to charterboat, fishing boat, and fishing resort operators. Catch rates declined in this area from about 0.66 fish per angler day observed during 1969-70 to 0.29 fish per day in 1977. This downward trend was reversed after 1977, and catch rates increased during 1978, 1979, and 1980 to 0.61, and then fluctuated between 0.41 and 0.62 from 1981 to 1983, declining to 0.32 in 1984 (Fig. 3).

Before the start of the Billfish Angler Survey in 1969, historical catch data obtained from the fishing resort of Rancho Buena Vista, located on Las Palmas Bay off the east coast of the southern tip of Baja California Sur, indicated a catch rate in the early 1960's of 0.6 to 0.9 striped marlin per angler day; the decline in the catch rate there from an estimated average of 0.75 in the early mid 1960's to about 0.30 fish per day in 1977 was substantial.

The average CPUE for striped marlin catches off Ecuador for 1978-84 was 0.83 fish per day, close to twice the rate of 0.46 fish per day recorded for Baja California Sur for the same period. The peak CPUE rates were also much higher, near 1.20 fish per day in 1978. However, the number of angler days reported was only 5 percent of that reported for Baja California Sur, making the Ecuador data less precise.

Striped marlin is the major billfish species reported from off Japan, and survey data were recently obtained from that

Table 2.—Reported catch, effort, and resulting CPUE rates for all locations in the Pacific having more than 1,000 angler days reported.

Location and year	Angler days	No. of billfish	Fish/ day	Days/ fish	Major species	Catch: Blue marlin	Striped marlin	Black marlin	Sailfish
Southern California									
1969	2,297	220	0.095	10.44	SM		220		
1970	2,068	232	0.11	8.91	SM		221		11
1971	2,093	192	0.90	10.90	SM		152		40
1972	2,212	119	0.05	18.59	SM		119		
1973	1,900	56	0.03	33.93	SM	10	46		
1974	4,409	460	0.10	9.58	SM	2	450		8
1975	2,678	247	0.09	10.80	SM	3	238		6
1976	2,848	275	0.10	10.36	SM		265		10
1977	3,383	381	0.11	8.88	SM	6	358		17
1978	5,684	429	0.08	13.25	SM	25	398	4	2
1979	4,921	438	0.09	11.24	SM	7	399	17	15
1980	3,900	429	0.11	9.09	SM	18	403	1	7
1981	2,997	453	0.15	6.62	SM	16	428	2	7
1932	2,666	296	0.11	9.01	SM	9	279		8
1983	2,696	485	0.18	5.56	SM	27	450		8
1984	2,874	397	0.14	7.49	SM	10	377		6
Total	49,626	5,109	0.10	9.71	SM	133	4,803	25	145
Hawaii									
1969									
1970	77	30	0.39	2.57	BLM	30			
1971									
1972	186	78	0.42	2.38	BLM	76			2
1973	84	12	0.14	7.00	BLM	10	1	1	
1974	1,003	100	0.10	10.03	BLM	88	12		
1975	677	77	0.11	8.79	BLM	76			1
1976	1,826	201	0.11	9.08	BLM	146	35	5	15
1977	1,984	432	0.22	4.59	BLM	345	33	8	46
1978	2,926	598	0.20	4.89	BLM	465	57	13	63
1979	2,017	441	0.22	4.57	BLM	315	76	20	30
1980	3,652	721	0.20	5.07	BLM	483	148	6	84
1981	1,448	327	0.23	4.43	BLM	248	44	2	48
1982	953	248	0.26	3.84	BLM	180	31	4	33
1983	1,377	361	0.26	3.81	BLM	264	62	6	29
1984	1,435	357	0.25	4.02	BLM	250	63	11	33
Total	19,645	3,983	0.20	4.93	BLM	2,976	562	6	384
Panama									
1969	26	24	0.92	1.08	SF				18
1970	115	76	0.66	1.51	SF				40
1971									
1972	193	131	0.68	1.47	SF				72
1973	157	159	1.05	0.96	SF		60	28	71
1974	304	348	1.14	0.87	SF		14	87	247
1975	167	279	1.31	0.76	SF		11	45	163
1976	293	235	0.80	1.25	SF		5	45	185
1977	377	288	0.76	1.31	SF	2	25	32	229
1978	340	325	0.96	1.05	SF	1	2	10	312
1979	347	265	0.76	1.31	SF	7	1	39	218
1980	418	353	0.84	1.18	SF	8	1	59	285
1981	455	457	1.00	1.00	SF	7	6	67	377
1982	417	554	1.33	0.75	SF	15	1	76	462
1983	178	82	0.46	2.17	SF	2		10	70
1984	243	364	1.50	0.67	SF	6	3	80	275
Total	4,025	3,880	1.04	0.96	SF	48	129	578	3,024

Location and year	Angler days	No. of billfish	Fish/ day	Days/ fish	Major species	Catch: Blue marlin	Striped marlin	Black marlin	Sailfish
Baja California									
1969	2,519	1,971	0.78	1.28	SM		1,657		314
1970	3,398	2,615	0.77	1.30	SM		2,258		357
1971	2,793	2,546	0.91	1.10	SM		2,253		293
1972	3,436	2,454	0.71	1.40	SM		2,207		244
1973	1,800	790	0.44	2.28	SM	67	600	31	92
1974	2,647	1,585	0.60	1.67	SM	66	1,307	6	206
1975	2,239	1,243	0.56	1.80	SM	35	1,058	21	129
1976	1,785	1,198	0.67	1.49	SM	47	897	14	240
1977	2,186	880	0.40	2.48	SM	39	643	10	188
1978	2,551	1,099	0.43	2.32	SM	58	855	6	180
1979	2,838	1,399	0.49	2.03	SM	88	1,175	8	128
1980	3,525	2,432	0.69	1.45	SM	91	2,143	20	178
1981	4,215	2,000	0.47	2.11	SM	94	1,722	25	159
1982	2,805	2,215	0.79	1.27	SM	129	1,735	22	329
1983	2,797	2,049	0.73	1.37	SM	500	1,307	31	211
1984	2,039	1,044	0.51	1.95	SM	203	659	7	170
Total	43,573	27,520	0.63	1.58	SM	1,417	22,476	201	3,418
Australia									
1969	755	398	0.53	1.90	BKLM			236	162
1970	262	69	0.30	3.32	BKLM			59	10
1971	357	157	0.44	2.27	BKLM			157	
1972	414	347	0.84	1.19	BKLM			347	
1973	357	543	1.52	0.66	BKLM		1	540	2
1974	558	493	0.88	1.33	BKLM	17	1	472	3
1975	540	327	0.61	1.65	BKLM			326	1
1976	689	423	0.61	1.23	BKLM	4	25	387	7
1977	706	621	0.88	1.14	BKLM	4	1	611	5
1978	1,036	539	0.52	1.92	BKLM	13	2	501	23
1979	574	319	0.56	1.80	BKLM	4	2	296	17
1980	1,119	601	0.54	1.86	BKLM	3	5	540	53
1981	503	215	0.43	2.34	BKLM	9	52	135	19
1982	662	381	0.58	1.74	BKLM	3	5	310	63
1983	560	353	0.63	1.59	BKLM		1	310	42
1984	886	471	0.53	1.88	BKLM	2	1	407	61
Total	9,978	6,257	0.63	1.59	BKLM	59	96	5,634	468
Mazatlan									
1969	583	704	1.21	0.83	SM		382		322
1970	461	588	1.28	0.78	SF		214		374
1971	272	305	1.12	0.89	SF		101		204
1972	290	300	1.03	0.97	SF		123		177
1973	294	188	0.64	1.56	SF	6	61		121
1974	190	184	0.97	1.03	SF	7	58	1	118
1975	115	125	1.09	0.92	SF	1	29	1	94
1976	150	140	0.93	1.07	SF	5	19	2	114
1977	149	118	0.79	1.26	SF	1	29	2	86
1978	218	111	0.51	1.96	SF	3	38		70
1979	125	104	0.83	1.20	SM	17	48	1	38
1980	144	141	0.98	1.02	SF	3	54	1	83
1981	136	113	0.83	1.20	SF		34	2	77
1982	99	63	0.64	1.57	SF	3	15		45
1983	110	64	0.58	1.72		8	8	2	46
1984	90	64	0.71	1.41	SF	10	1	1	52
Total	3,426	3,312	0.97	1.03	SF	64	1,214	13	2,021

Continued on next page.

Table 2.—Continued. Reported catch, effort, and resulting CPUE rates for all locations in the Pacific having more than 1,000 angler days reported.

Location and year	Angler days	No. of billfish	Fish/ day	Days/ fish	Major species	Catch: Blue marlin	Striped marlin	Black marlin	Sailfish
New Zealand									
1969									
1970	41	3	0.07	13.67	SF		3		
1971									
1972	15	1	0.07	15.00	BKLM			1	
1973	8	0							
1974	5	2	0.40	2.50	BLM	2			
1975	146	74	0.51	1.97	BKLM	4	10	60	
1976	36	3	0.08	12.00	SM		3		
1977	191	17	0.09	11.24	SM		16		1
1978	320	35	0.11	9.14	SM		35		
1979	169	21	0.12	8.05	SM		19	2	
1980	273	42	0.15	6.50	SM	1	40	1	
1981	457	39	0.09	11.72	SM	6	30	2	1
1982	297	46	0.15	6.46	SM	1	45		
1983	631	79	0.13	7.99	SM	6	66	2	3
1984	473	50	0.11	9.46		7	38	4	1
Total	3,062	412	0.13	7.43	SM	27	307	72	6
Acapulco/Zihautanejo/Ixtapa									
1969	112	111	0.94	1.05	SF		5		106
1970	97	84	0.87	1.15	SF		9		75
1971	40	42	1.05	0.95	SF		2		40
1972	64	44	0.69	1.45	SF		3		41
1973	30	35	1.17	0.86	SF		10		25
1974	42	53	1.26	0.79	SF		1		52
1975	106	71	0.67	1.49	SF		12		59
1976	96	150	1.56	0.64	SF		3	1	146
1977	314	456	1.45	0.69	SF		6	1	449
1978	114	100	0.88	1.14	SF			1	99
1979	227	218	0.96	1.04	SF		5		213
1980	69	81	1.17	0.85	SF		5		76
1981	105	122	1.12	0.89	SF		1		121
1982	46	44	0.96	1.05	SF				44
1983	100	87	0.87	1.15	SF	1	2	1	83
1984	78	62	1.26	0.79	SF	4		1	57
Total	1,644	1,760	1.07	0.93	SF	5	64	5	1,686
Guaymas/Kino/Pta. Penasco									
1969									
1970									
1971	67	50	0.75	1.34	SF				50
1972	64	17	0.27	3.76	SF				17
1973	38	20	0.53	1.90	SF				20
1974	53	24	0.02	2.21	SF		2		21
1975	143	34	0.24	4.21	SF				34
1976	100	42	0.42	2.38	SF	1	4		37
1977	86	16	0.19	5.38	SF				16

Location and year	Angler days	No. of billfish	Fish/ day	Days/ fish	Major species	Catch: Blue marlin	Striped marlin	Black marlin	Sailfish
Ecuador									
1969	51	68	1.33	0.75	M		56		12
1970	41	79	1.93	0.52	M		75		4
1971									
1972	25	20	0.80	1.25	SM		16		4
1973	65	48	0.74	1.35	SM	1	28		19
1974	192	122	0.64	1.57	SM		79	1	42
1975	111	126	1.14	0.88	SF	2	48	1	75
1976	217	179	0.82	1.21	SF	2	35	3	139
1977	238	104	0.48	2.09	SM	1	69	2	42
1978	180	127	0.71	1.42	SF		61	2	64
1979	180	205	1.14	0.88	SM	1	192		12
1980	250	294	1.18	0.85	SM	5	248	8	33
1981	239	145	0.61	1.65	SM	4	137		7
1982	187	189	0.99	1.01	SM	13	163	6	7
1983	94	88	0.94	1.07	SM	19	49	4	16
1984	292	200	0.68	1.46	SM	17	144	15	24
Total	2,362	2,004	0.85	1.18	SM	65	1,322	42	500
Costa Rica									
1969									
1970	7	0							
1971									
1972									
1973	1	1	1.00	1.00	SF				1
1974									
1975	30	85	1.83	0.35	SF				85
1976	78	100	1.28	0.78	SF				100
1977	537	462	0.86	1.16	SF	1	1	3	457
1978	58	63	1.09	0.92	SF			1	62
1979	120	138	1.15	0.87	SF	3	5	1	129
1980	183	199	1.09	0.92	SF	5	5	4	185
1981	228	184	0.81	1.24	SF	2	29	4	149
1982	196	247	1.26	0.79	SF	4	5	15	223
1983	199	254	1.28	0.78	SF	6	2	8	238
1984	140	303	2.16	0.44	SF	4	3	17	279
Total	1,777	2,036	1.15	0.87	SF	25	50	53	1,908
Guaymas/Kino/Pta. Penasco									
1978	105	16	0.15	6.56	SF				16
1979	175	37	0.21	4.73	SF				37
1980	106	11	0.01	9.64	SF		4		7
1981	127	27	0.21	4.70	SF	1	12		14
1982	112	5	0.04	22.40	SF		2		3
1983	67	10	0.15	6.70	SF		1	2	7
1984	191	30	0.16	6.37					30
Total	1,434	339	0.24	4.23	SF	2	25	3	309

Table 3.—Reported catch, effort and resulting CPUE rates for locations having a response level of less than 1,000 angler days.

Location	Angler days	No. of billfish	Fish/day	Days/fish	Major species
Manzanillo, Mex.	928	595	0.64	1.56	SF
Thailand	522	243	0.47	2.15	BKLM
Guatemala	435	178	0.41	2.44	SF
Tahiti	434	124	0.29	3.50	BLM
New Guinea	386	92	0.24	4.20	SF
San Blas, Mex.	320	224	0.70	1.43	SF
Guam	265	45	0.17	5.89	BLM
Fiji	159	9	0.06	17.67	SF
Philippine Islands	122	37	0.30	3.30	SF
Samoa	93	10	0.11	9.30	BLM
Puerto Vallarta, Mex.	90	52	0.58	1.73	SF
Peru	38	9	0.28	4.22	SM
Japan	78	38	0.43	2.05	SM
Clipperton Island	23	1	0.04	23.00	SF
Columbia	34	33	0.97	1.03	SF
Marshall Islands	18	4	0.22	4.50	BLM
Revillagigedo Islands	18	3	0.17	6.00	SM
New Caladonia	12	0			
Nicaragua	2	8	4.00	0.25	SF
Yap Island	7	1	0.14	7.00	BLM
Topolobampo, Mex.	7	3	0.43	2.33	SF
El Salvador	6	6	1.00	1.00	SF
Palau	6	2	0.33	3.00	BKLM/SF
Borneo	4	1	0.25	4.00	BKLM
Chile	3	0			
Cook Island	4	0			
China	3	0			

fishery. From data obtained in 1982 and 1983, the catch rate was 0.49 striped marlin per angler day, only slightly less than the 1981-83 average of about 0.53 fish per day for Baja California Sur.

Environmental changes can have a significant impact on CPUE rates by modifying the distribution and behavior of the fish. The years of 1982-83 was an El Niño period of warmer sea surface temperature in the eastern Pacific. The effect of this environmental change was evident from the change in abundance/availability of several billfish species around the southern tip of the Baja California peninsula. Striped marlin CPUE dropped from the 1982 level of 0.62 fish per day to 0.47 in 1983 and to 0.32 fish per day in 1984. Though striped marlin had become less abundant around the tip of Baja California, a joint-venture Mexican/Japanese commercial longliner operation working to the west and southwest of the southern tip of Baja California (Cabo San Lucas) did obtain CPUE rates comparable to those of previous years. Blue marlin CPUE increased substantially during the El Niño of 1983 from an average of 0.03 fish per day (1973-82) to 0.18 fish per day in 1983 and continued at a rate of 0.10 in 1984. In 1983 and 1984 the center of the California catch correspondingly shifted to the northwest between San Nicolas Island and the Santa Barbara Channel Islands. This area is northwest of the normal catch areas around Catalina Island, between Catalina Island and the mainland, and off San Diego. Sea surface temperatures were very warm off southern California during the 1983 El Niño and were higher in 1984; catches of striped marlin increased with a record of CPUE rate of 0.16 fish per day in 1983 and 0.13 fish per day in 1984. These increases were related to above average sea surface temperatures off the northwest coast of Baja California and southern California (Squire, 1974).

Blue Marlin

Blue marlin is common to tropical oceans and is a dominant billfish species in the central Pacific area from the Tuamotu Islands in the southeast to the Marianas Islands in the northwest. These areas appear to be the major habitat of blue marlin. Commercial longline catches of this species declined in the Pacific to about 12,500 metric tons (t) in 1975, but since 1975 catches have increased.

Angler catch rates for blue marlin are normally lower than those observed for striped marlin and sailfish (Fig. 4). However, the size of this species (up to 2,000 pounds-plus) makes it an attractive sportfish. Limited survey data from Tahiti and Guam show CPUE rates that are not substantially different from those of Hawaii. CPUE rates ranged from 0.16 to 0.28 fish per day in 1984.

Angler response from Hawaii was high compared with that of other island areas in the central Pacific. In 1970 and 1972 Hawaiian catch rates for blue marlin were considerably higher than in 1973-83; however, the sample size in the early 1970's was small compared with that of later years. Blue marlin catch rates have increased from about 0.10 fish per day during 1973-76 to nearly 0.25 fish per day in 1984.

Although the angler response rate is low for the Tahiti areas, data collected since 1976 indicate an average CPUE rate of 0.23 fish per day. This is above the Hawaiian Islands average of 0.18 fish per day for the same period. The CPUE

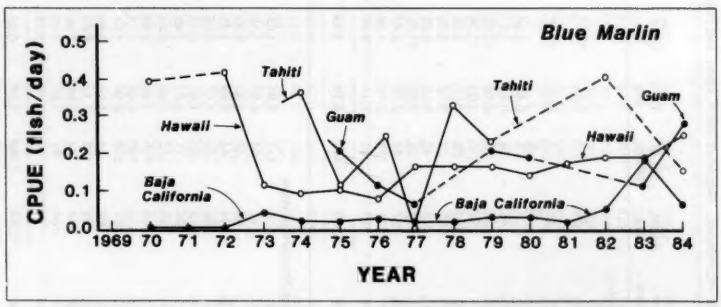

Figure 4.—Catch rates for blue marlin in areas having a response rate of greater than 200 angler days.

rate for blue marlin caught off Baja California Sur is usually very low (0.03 fish per day average), except for the El Niño years of 1982-83 when the CPUE rate increased to 0.18 fish per day, a CPUE similar to that observed for the central Pacific Ocean.

Black Marlin

The center of black marlin distribution is in the southwest Pacific and Indo-Pacific area. High angler CPUE rates were recorded for the area along the Great Barrier Reef, Queensland, Australia, located on the western edge of the Coral Sea. Angler catch rates for black marlin in areas having a response rate greater than 200 angler days are shown in Figure 5.

Large fluctuations in catch rates for black marlin were observed off Queensland during the early years of the survey (Fig. 5). High catch rates of up to 1.5 fish per angler day were observed in 1971 and 1973. The rates declined to a level of about 0.5 fish per day in 1978 and since then remained near that level. The average CPUE for 1976-84 is 0.54. This fishery produces large fish and many of the catches are in excess of 300-400 pounds. Considering that the CPUE is about 0.5 fish per day, the catch per angler in weight is one of the highest in the world. Thailand reported an angler CPUE rate of 0.44 fish per day, only slightly less than that observed for the Queensland area; however, the fish caught off Thailand were not as large as those caught off Queensland, Australia (pers. commun.). In the eastern Pacific Ocean some black marlin are landed in the tropics off Central and South America, and billfish anglers fishing in Panama report an average CPUE rate of 0.11 fish per day.

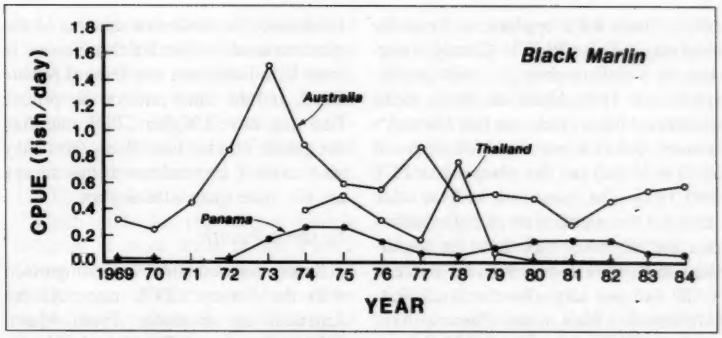

Figure 5.—Catch rates for black marlin in areas having a response rate of greater than 500 angler days.

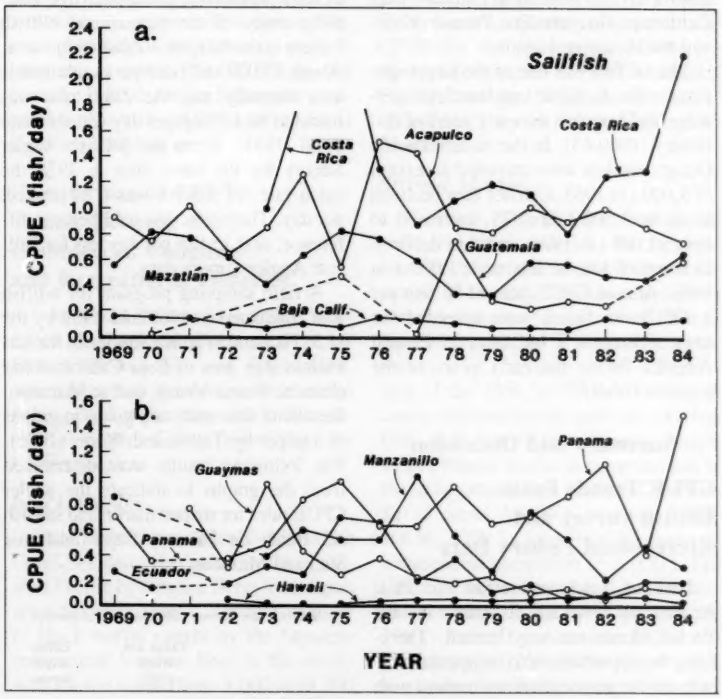

Figure 6.—Sailfish catch rates for areas (a and b) having a response of greater than 400 angler days.

Sailfish

High commercial and recreational CPUE rates for sailfish are observed along the eastern Pacific coast from Panama to the Gulf of California, Mex. This area has the highest abundance of sailfish in the eastern Pacific. Abundance is highest along the coast from near Acapulco, Mex., south to off Costa Rica and Panama during the winter. In the spring and summer, sailfish move northward and have been recorded in the northern part of the Gulf of California (lat. 31°N). The number of survey responses is low for anglers fishing in areas of high sailfish catches. Catch rates for Costa Rica, Guatemala, Mexico (Baja California Sur, Mazatlán, Manzanillo, Guaymas/Pta. Penasco/Kino, and a Acapulco/Ixtapa), Ecuador, and Hawaiian areas as well are given in Figure 6a-b. These areas have substantial catches of sailfish and an angler response rate of 400 or more angler days. The CPUE rate for fishing off Acapulco/Ixtapa, Mex., an area near the center of Pacific sailfish distribution, averages about 1.0 fish per

day. Costa Rica appears to have the highest sailfish CPUE in Central America; its CPUE reached 2.17 fish per angler day in 1984. Mazatlán, Mex., to the northwest has a catch rate that fluctuates around 0.5 fish per day with highs of 0.81-0.82 fish per day observed in 1970 and 1975. The ranges for sailfish catch rates for the southern tip of Baja California Sur are lower than those for Mazatláns and appear to be relatively stable at 0.08 fish per day. To the southwest, Manzanillo, Mex., and Panama have sailfish CPUE rates of 0.50-0.80 fish per angler day. CPUE rates below 0.50 were recorded from Guatemala, Ecuador, Baja California, Guaymas/Pta. Penasco/Kino, and the Hawaiian Islands.

The sailfish was one of the target species for the Japanese longline fleet operating off Mexico in the early years of that fishery (1960-65). In the eastern Pacific Ocean, catches were recorded in excess of 9,000 t in 1965. Catches then declined to about 3,500 t in 1975, increased to over 10,000 t in 1976, and then declined to a record low of less than 1,000 t in 1981. Annual CPUE rates of 90 fish per 1,000 hooks fished were recorded for some 5° long. × 5° lat. areas off Central America during the early years of the longline fishery.

Summary and Discussion

CPUE Trends From Billfish Survey and Recreational Fishery Data

Data on catch and effort for most recreational billfish fisheries in the Pacific Ocean are very limited. Therefore, the opportunities to compare the results of the postcard survey method with catch rates developed by other methods are few. Although some fishing resort operations maintain fishing records, these records are in most cases insufficient for generating CPUE values comparable to the records of the Billfish Angler Survey. Records for the resorts are maintained in "numbers of boat days," which poses the problem of the number of angler days actually represented. Charter boats may at times fish for species other than billfish, and this could result in CPUE error. In some areas (Baja California), a substantial amount of angler response to the Billfish Survey is from U.S. fishermen who fish off private boats, and the catch rate for this private fleet may have a higher CPUE rate than the public charter boat fleet. Bias may also result if respondents to this survey are the more successful anglers.

Eastern Pacific

Some data suitable for comparison with the Survey CPUE rates off the Americas are available. From March 1978 to February 1979, biologist Hector Zurita Brito of Mexico's Departmento de Pesca conducted a comprehensive sampling study of the recreational billfish fishery in the Acapulco/Zihuatanejo area. About 30,000 sailfish were caught in this area annually and the catch rate was found to be 1.0 fish per day (Zurita Brito 1980, 1985). From the Billfish Angler Survey for the same area in 1978 the catch rate for sailfish was 0.87 sailfish per day. There was thus a 13 percent difference, or 0.13 fish per day less for Billfish Angler Survey data.

A field sampling program for billfish was conducted in 1968 and 1969 by the U.S. Fish and Wildlife Service in the Las Palmas Bay area of Baja California Sur (Rancho Buena Vista), and at Mazatlán. Results of this study are given in graphs in a paper by Talbot and Wares (1975). The following results were determined from the graphs to indicate the angler CPUE rates for striped marlin and sailfish off Bahia de Palmas (Baja California Sur) and Mazatlán.

Billfish Angler Survey, 1969 (first year of Survey).

	Talbot and Wares (1975)	Billfish Angler Survey
Striped marlin		
Mazatlán	0.45	0.66
Baja Calif.	0.60	0.66
Sailfish		
Mazatlán	0.60	0.55
Baja Calif.	0.10	0.12

A limited amount of catch/effort data from a leading fishing resort in the East Cape area of Baja California, located on Bahia de Palmas, was made available; analysis of these data indicate a striped marlin CPUE rate much lower than that recorded by the Survey:

Year	Billfish Angler Survey CPUE	Fishing Resort CPUE
1981	0.41	0.13
1982	0.62	0.16
1983	0.47	0.22 (first half year)

For Ecuador, fishing resort data had boat days only. The CPUE calculated using an estimated angler days effort (boat days multiplied by two) appeared more compatible with data from the Billfish Angler Survey than were sample data from Baja California:

Year	Billfish Angler Survey CPUE	Fishing Resort CPUE
1972	0.53	0.64
1973	0.35	0.43
1974	0.29	0.41

Angler catch rates for strpied marlin at both locations appear not to be comparable with catch rates from the Billfish Angler Survey. Ecuador resort data, even though they were from a much smaller sample than the Baja California survey data (2,070 angler days vs. 41,534 angler days), were in better agreement with the Survey than the Baja California resort data.

Central and Western Pacific

Recent studies of the Hawaiian Island billfish fisheries provide a source of comparative data. Holland (1985) reported that by examining the number of marlin flags on charterboats entering Kewalo Basin, Honolulu, Hawaii, he was able to determine the number of marlin caught by this fleet. A measure of effort for full-day charters from the Kewalo Basin fleet indicated that the CPUE rate was one marlin per 6.25 days of fishing or 0.16 fish per boat day. On the other hand, Samples et al.[1], from economic survey data, reported that the 119 charterboats around the Hawaiian Islands fished an average of 155 trips per year catching an average of 47 billfish (striped, blue, and black marlin, sailfish, swordfish, and shortbill spearfish, *Tetrapturus angustirostris*). From this figure the total

[1]Samples, K. C., J. Kusakabe, and J. Sproul. 1984. A description and economic appraisal of charterboat fishing in Hawaii. NMFS Honolulu Lab. Admin. Rep. H-84-6C, 130 p.

catch would be 5,593 billfish, reported to be taken by a total of 73,780 anglers, given a statewide CPUE of 0.08 billfish per angler day.

These surveys, however, do not indicate the charterboat trips that fished marlin as one of 13 groups of targeted fishes. From Samples et al.[1] data for the island of Hawaii, which has a higher percentage (14.8 percent) of billfish in the charterboat catch than the data from the islands of Oahu or Maui, the billfish CPUE rate (based on 128 days fishing per charterboat, a catch of 58 billfish, and an estimated three anglers per trip) is calculated to be 0.15 billfish per angler day. The Pacific Billfish Angler Survey CPUE for the Hawaiian Islands for 1978-84 is 0.13-0.19 fish per angler day with an overall average of 0.16 fish per angler day, which is comparable to the rates reported by Holland (1985) (though the Survey rates were higher than his during 1982-83) and by Samples et al.[1] The Billfish Angler Survey form does not separate response data by island.

Sample heterogeneity must account for much of the CPUE differences during comparable years. The Samples et al.[1] data represent findings from a statewide questionnaire; Holland's data are from the fishing grounds off the island of Oahu, not the best marlin fishing area in the Hawaiian Islands (Holland, 1985). The highest catch rates are recorded off the Kona coast of the island of Hawaii (Samples et al.[1]), and the CPUE rates there are most like to those determined by the Billfish Angler Survey. The Billfish Angler Survey should be biased toward higher CPUE values because the respondent base is made up of anglers who are active in billfish fishing and who fish the higher density areas of billfish; it is possible that the better billfish anglers are primarily responding. Hawaiian angler catch rates of blue marlin, the major target species in the Hawaiian Islands area, are not as high as those observed for striped marlin and black marlin in other important recreational fishing areas. This is probably because the Hawaiian Islands are not geographically near the center of distribution for blue marlin while that is the case for the recreational fisheries for striped marlin about the tip of Baja California Sur and for black marlin near the Great Barrier Reef off Queensland (Suzuki and Honma[2]). The distribution of blue marlin in the Pacific Ocean is centered in the south central Pacific Ocean (lat. 10°-20°S × long. 140°-160°N) from December to February and in the northwest central Pacific (long. 120°E) from June to August.

Catch rates for recreational billfish fisheries in most areas of the Pacific Ocean are relatively stable compared with the trend of catch rates observed for striped marlin about the southern tip of Baja California Sur, and for black marlin off the Queensland coast. Both of these productive recreational fishing areas are located near commercial longline fisheries that targets on these species. In summary, it appears that CPUE's derived from the Billfish Angler Survey are comparable to other angler surveys unless there are sampling errors.

Comparison of CPUE Trends Between the Commercial Longline and Recreational Fisheries

I compared the trends in CPUE's between geographical areas, such as off Baja California Sur and Queensland, which have both an intensive recreational fishing (high angler response) and a commercial longline fishery (high CPUE) for billfish species.

Black Marlin

Black marlin have been fished in the Coral Sea and other areas in the southwest Pacific by longline fleets from Japan since the early 1950's. The total number of black marlin caught by the Japanese commercial longline fleet in the southwest Pacific ranged from 4,000 to 14,000 fish per year during 1969-80. During this same period, CPUE rates calculated by 3-year periods indicate a decline from an average of 0.17 fish per 1,000 hooks (1969-71) to 0.07 fish per 1,000 hooks (1978-80) a 57 percent decline in CPUE (Anonymous, 1980).

Angler catch rates for black marlin off Australia peaked in 1973 at about 1.5 fish per angler day. This peak may have been due to fleet expansion to new grounds and increased efficiency of the charter fleet during the early 1970's when the recreational black marlin fishery was developing rapidly off the Cairns area and also north of that area. The angler CPUE average for the 1971-75 period, 0.83, declined to 0.46 fish per angler day for 1979-1984, a 45 percent decline in angler CPUE. The commercial longline CPUE for the southwestern Pacific for 1972-74 was 0.11 fish per 1,000 hooks. This declined to 0.07 fish per 1,000 hooks in 1978-80, a 36 percent CPUE decline. Thus, for a comparable time period the CPUE for the commercial fishery declined 36 percent for the southwest Pacific, and the CPUE for the recreational black marlin fishery declined 45 percent.

Striped Marlin

The 1969-76 catch of striped marlin per 1,000 hooks fished by the Japanese commercial longline fleet off the southern tip of the Baja California peninsula correlated positively with the CPUE of the recreational fleet as determined by the Survey (Fig. 7; Squire, 1982). Regression of the 1969-76 CPUE's for striped marlin attained by the Japanese longline fleet with that of recreationally caught striped marlin for the same period and in the same general area off Baja California Sur (5° areas, lat. 20°N by long. 105°W and lat. 20°N by long. 110°W) produced a reasonable correlation ($r = 0.81$). The CPUE of the Japanese longline fleet was much higher in the early and middle 1960's, before the start of the billfish angler survey in 1969, and it is reasonable to assume, based on historical data, that the angler CPUE was also higher. The limited amount of recreational fishery data available would support this.

Decline in the commercial longline catch rate of striped marlin off Baja California Sur appeared to be greater than that observed for recreational billfish anglers (Fig. 7). If CPUE rate is related to stock size, then the Survey could be measuring changes in stock size for a major area of fishing in the eastern Pacific. This is plausible because the area around the southern tip of Baja California Sur ac-

[2]Suzuki, Z., and M. Honma. 1977. Stock assessment of billfishes in the Pacific. Draft working paper, Billfish Stock Assessment Workshop, NMFS Honolulu Laboratory, Hawaii, 5-16 December 1974.

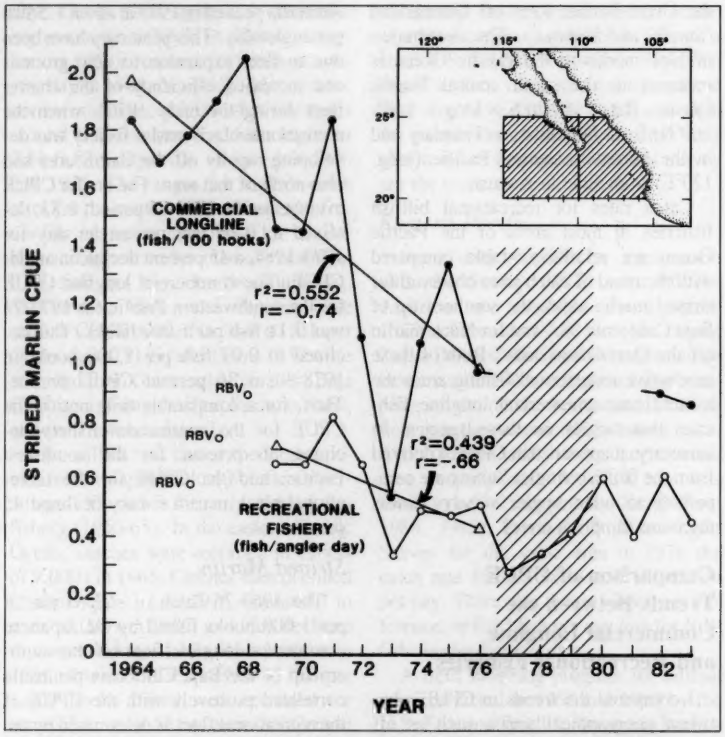

Figure 7.—Striped marlin CPUE and its regression for the commerical longline fleet 1964-76, two 5° long. bv 5° lat. areas, and the Billfish Angler Survey for the southern portion of Baja California. The hatched area represents a period when longline operations were negligible within Mexico's 200-mile economic zone.

counts for about 25 percent of the commercial striped marlin catch in the eastern Pacific (east of long. 130°W). Downward CPUE trends in both sport and commercial fisheries indicate that the commerical longline fishing may have had an impact on the lower recreational billfish catch rates.

Longline fishing by foreign fishermen off Mexico for striped marlin, sailfish, and swordfish was interrupted in the spring of 1977 due to the enforcement of Mexico's 200-mile economic zone, which prohibited fishing by foreign fishermen except by permit from the government. In 1977 and 1978 no longline effort and catches of striped marlin were reported by the Japanese Fishery Agency from around the tip of Baja California Sur, an area that produces some of the highest catch rates for striped marlin in the Pacific (Anonymous, 1956-80). As part of joint ventures between Mexico, Japan, Taiwan, and Korea, commercial longline fishing targeting on striped marlin, swordfish, and to a lesser extent on sailfish, was resumed in 1980. Effort and catch increased in 1981 and 1982. Longline catch data on the number of striped marlin per 1,000 hooks fished from portions of the joint venture longline operations about the southern tip of Baja California Sur are available for 1982 and 1983 (personal commun.). Striped marlin CPUE was calculated based on a 1982 catch of 13,489 fish using 1,494,610 hooks to give a CPUE of 9.03 fish per 1,000 hooks. The 1983 CPUE was 8.71 fish per 1,000 hooks fished based on a catch of 18,931 striped marlin using 2,104,716 hooks. The CPUE rate for 1982-83 is only slightly less than the CPUE rate the Japanese longliners experienced in 1976, before elimination of foreign longline fishing within Mexico's 200-mile economic zone.

The Billfish Angler Surveys in 1978, 1979, and 1980 show an increase in angler catch rate for Baja California Sur, reversing the downward trend of angler CPUE from 1969 to 1976 (Fig. 3, 7). The CPUE subsequently declined in 1983 to 1984.

The relaxation of commercial fishing effort in a local area (200 n.mi. zone) appears to have had a positive impact on billfish angler catch rates. Although recreational and commercial CPUE's noted in this paper and by Pristas (1980) appear to be positively correlated, the CPUE's may be following changes in local availability—that is, the fishing may not be noticeably affecting the total stock.

The economic value of recreational fishing for the large pelagics such as tunas and billfishes is substantial (Radonski, 1984; Herrick[3]). High catch rates of black marlin off Queensland, Australia, attract anglers from throughout the world, as does the high catch rates of billfish off Baja California Sur, Mexico. In some areas, such as about the tip of Baja California Sur, the recreational fishery is very important to the local economy.

It is important for fishery managers to know the economic value of the fishery and the level and trend of billfish angler catch rates as well. In southern California about 3,000 private boats are equipped with billfish fishing gear (Anonymous, 1979), yet the angler catch rate for striped marlin there is low—0.1 ± fish per day. Even at this low CPUE level, anticipation of a catch is great enough to warrant substantial expense and effort by

[3]Herrick, Samuel F., Jr. 1984. Socio-economic profile of the southern California billfish angler. NMFS Southwest Fish. Cent. Admin. Rep. LJ-84-12.

mostly local marine anglers. However, if the catch rates for striped marlin about the southern tip of Baja California Sur were to decline to such low levels (0.2-0.3 fish/angler day), foreign billfish anglers would be reluctant to undergo the expense and time to travel there and experience what would be rated as poor fishing for that area.

Summary

Data presented in this paper showing declines in commercial longline CPUE in relation to changes in angler CPUE for striped marlin off Baja California Sur and black marlin off Queensland suggest that recreational billfish fisheries are being affected by the commercial longline fisheries. The same was suggested by Pristas (1980) for billfish species in the Gulf of Mexico. When commercial longline fishing was curtailed within Mexico's 200 n.mi. economic zone in 1977-80, the recreational CPUE for striped marlin increased, which would be expected if the commercial fishery were having an effect.

However, in evaluating the relationship between the oceanic longline and localized, coastal recreational fisheries, it should be kept in mind that billfish are highly migratory and not likely to form local, vulnerable populations; the difference in total catch between most recreational and commercial fisheries is usually several orders of magnitude in favor of the commercial longline fishery; the magnitude of the effect of longline fishing on a localized recreational fishery may only be accurately measured by angler catch rate in geographical areas where density and availability of a particular billfish stock are increased especially for the recreational fishery. In the eastern Pacific the mechanism by which the abundance of striped marlin is reflected in the localized recreational catch from off Baja California Sur may be high mobility of the fish throughout the eastern Pacific commercial fishing grounds coupled with increased availability when the fish nears the recreational fishing area.

Results from the Billfish Angler Survey indicate that management of pelagic billfish resources, where both commercial and recreational fisheries are participants, may require a determination of the minimum allowable angler catch rate based on socioeconomic analysis. This catch rate can be used as a bench mark when considering regulations that affect the interests of both the commercial and recreational fisheries.

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Striped Marlin, *Tetrapturus audax*, Migration Patterns and Rates in the Northeast Pacific Ocean as Determined by a Cooperative Tagging Program: Its Relation to Resource Management

JAMES L. SQUIRE

ABSTRACT—Migration patterns and rates for striped marlin, Tetrapturus audax, *tagged and recaptured in the northeast Pacific Ocean during 1957-81 are reported by time period and analyzed. Few long-range migrations and no trans-Pacific migrations were observed. Comparisons are made with other types of physical and biological data that might indicate seasonal movement (i.e., longline catch rates, areas of striped marlin spawning, movement of thermocline depth relative to fishing success). A tentative hypothesis describing the seasonal movement of striped marlin in the northeast Pacific and the total eastern Pacific is also proposed and presented in graphic form.*

Introduction

Since billfish cannot be captured in large numbers to study movements through tagging studies, marine anglers who will tag and release fish provide an effective, alternate way to obtain information on migration patterns. Billfish tagging by marine anglers in the Pacific began in the middle 1950's when tagging equipment, distributed to anglers by the Woods Hole Oceanographic Institution's (WHOI) Cooperative Marine Game Fish Tagging Program for tagging tunas and billfish in the Atlantic, was transported to fishing areas in the Pacific.

Sailfish, *Istiophorus platypterus*, were first tagged by billfish anglers in the northeast Pacific in 1954, and striped marlin, *Tetrapturus audax*, were first tagged in 1957. In 1961, black marlin, *Makaira indica*, were first tagged in the southwest Pacific (Coral Sea), and in 1963 blue marlin, *Makaira nigricans*, were tagged in the central Pacific (Squire, 1974). Cooperative billfish tagging programs with rod-and-reel anglers were developed to obtain an understanding of migratory patterns that could be useful in developing management plans for Pacific billfish stocks.

In 1963, the U.S. Fish and Wildlife Service's Pacific Marine Game Fish Research Center, Tiburon Marine Laboratory, Tiburon, Calif., under the U.S. Department of Interior, assumed responsibility from WHOI for support of the Cooperative Marine Game Fish Tagging Program in the Pacific area. In 1970 a reorganization transferred the Tiburon Laboratory and the tagging program to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) in the U.S. Department of Commerce. From 1963 to 1970 the State of California's Department of Fish and Game (CDFG) also provided tags to a select group of cooperating anglers to tag striped marlin (Squire, 1974).

The angler tagging programs have now accounted for nearly all the tagged billfish in the Pacific at a relatively modest cost compared to that which would have been incurred had the same fish been caught and tagged by more efficient longline gear from research vessels. These billfish were tagged mainly in areas that support active recreational billfish fisheries.

There is a major recreational fishery for striped marlin in the northeastern Pacific centered about the southern tip of Mexico's Baja California Sur peninsula, and it is very important to the economy of that area (Talbot and Wares, 1975). High catch rates are recorded in this area and surveys show the catch per angler day has ranged from 0.3 to 0.8 striped marlin since 1969 (Squire, 1986). Some striped marlin are also landed at Mazatlán, Mex., and others are occasionally taken off other west coast ports of Mexico and off Central and South America. High catch rates are observed again off Ecuador. In the northeast Pacific, high catch rates for striped marlin are recorded from January to March off Mazatlán, Mex., and later in the year (April-October) about the southeastern tip of the Baja California peninsula (Eldridge and Wares, 1974). The U.S. recreational fishing fleet off southern California lands striped marlin from July through October, with catches usually peaking in September; this area is the northern limit of the recreational fishery in the eastern Pacific.

Longline fishing for billfish and tunas has been conducted in the eastern Pacific (east of long. 130°W.) since the late 1950's (Suda and Schaefer, 1965) and in the northeastern Pacific, where it has targeted on striped marlin, sailfish, and swordfish, *Xiphias gladius*, since 1963 (Joseph et al., 1974). The catch rate for striped marlin in the high catch rate areas of the northeastern Pacific has declined from about 18 fish per 1,000 hooks fished in the early 1960's to about 9-11 fish per 1,000 hooks fished in 1980 (Anonymous, 1962-80). This decline came during the time tagging was conducted. Despite the substantial catch rate decline since the beginning of the fishery, the rate is among the highest in the Pacific, and this longline fishery provides in excess of 80 percent of the billfish tags recovered. From early 1977 to 1980 longline fishing for billfish and

James L. Squire is with the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.

tunas was prohibited by the Government of Mexico within its 200-mile economic zone. The highest catch rates for striped marlin are about the southern tip of Baja California Sur, within the 200-mile zone. Joint-venture longline operations were resumed in 1980, providing a source of striped marlin tag recoveries.

Between 1964 and 1981, 155 tagged striped marlin were recovered—the majority by foreign commercial longline vessels. From recovery records it is possible to reconstruct migration patterns and rates. In this study I discuss the factors affecting tagging and recovery as they relate to migration, and the implications of the results for fishery management.

Tagging Methods and Results

Methods

According to the tagging instructions, when the billfish is brought alongside the boat the angler is to insert the dart tag beside the dorsal fin. Descriptive literature illustrating the suggested point of tag insertion is distributed with the tagging equipment. Because tagging of a large active billfish that cannot be lifted from the water or partially immobilized is a difficult task, it is probable that many tags have not been inserted as recommended.

When the tagging equipment is distributed to the angler, the tags are attached to a postcard (tag report card) which indicates the serial number of the tag (Fig. 1). After tagging a fish, the angler is requested to complete the tag information card with the date, location, species, estimate of marlin's weight and length, and the tagger's name and address; the angler is requested to return the card to the organization issuing the tag.

Tags used by billfish anglers participating in the Cooperative Marine Game Fish Tagging Program were described by Squire (1974). Four types of tags have been used for tagging striped marlin in the northeast Pacific Ocean (Fig. 1). For tagging conducted under NMFS sponsorship, less than 1 percent of the striped marlin were tagged with type "A" tags. About 7 percent were type "B" or FT-1, 37 percent type FM67, and 56 percent type FH69 or "H" type. The percentage of tag types used in the three areas of tagging was similar to the above distribution percentages, with one exception. A low percentage (4 percent) of FH69 tag were used at Mazatlán, due to a substantial reduction in tagging effort there in the early 1970's, at about the time the FH69 tag was introduced.

Figure 1.—Dart tags and tag report card used by the NMFS for the cooperative tagging program for tagging striped marlin in the northeast Pacific Ocean.

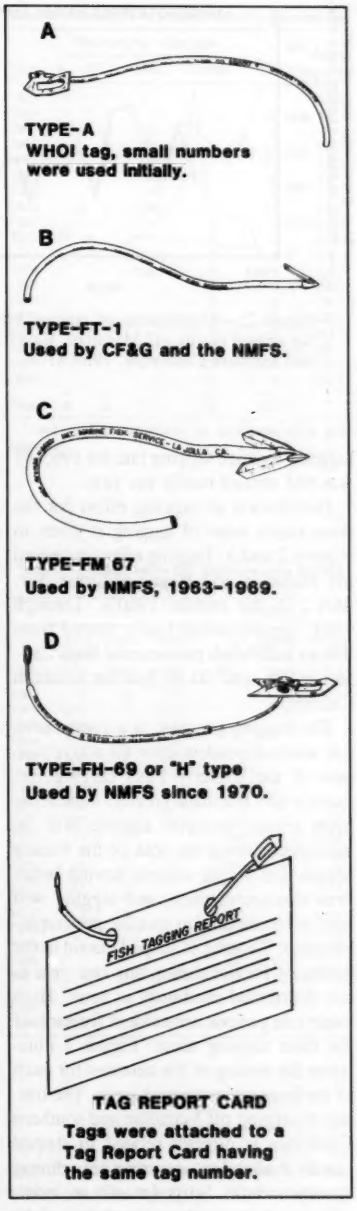


Table 1.—Annual number of striped marlin tagged by Cooperative Marine Game Fish Tagging Program Agency, 1957-81.

Year	CDFG	WHOI	NMFS			Total
			California	Baja Calif. Sur	Mazatlán	
1957		17	—	—	—	17
1958		13	—	—	—	13
1959		10	—	—	—	10
1960		2	—	—	—	2
1961		87	—	—	—	87
1962		76	—	—	—	76
1963	18	942	6	7	—	973
1964	329	113	9	243	8	702
1965	253	52	3	208	7	523
1966	186	47	13	365	15	626
1967	107	31	14	432	166	750
1968		29	17	749	59	854
1969	1	5	12	406	39	463
1970	2	6	24	617	54	703
1971		9	13	827	7	856
1972		—	7	804	1	812
1973		—	2	344	3	349
1974		—	54	603	3	660
1975		—	15	473	1	489
1976		—	46	576	9	631
1977		—	37	315	—	352
1978		—	24	557	—	581
1979		—	42	458	—	500
1980		—	22	1,142	—	1,164
1981		—	60	641	—	701
	896	1,439	420	9,767	372	12,894

Tagging Results

Between 1957 and 1981, 12,894 striped marlin were reported tagged in the northeast Pacific. This number represents only those tags for which a tag card was returned to the agency distributing the tags. Table 1 gives the number of striped marlin tagged by agencies that have provided tags to cooperating marine anglers. During 1963-81 the NMFS program accounted for 10,559 striped marlin tagged or 82 percent of the total number tagged. Maximum tagging effort was in 1980 (1,164 striped marlin tagged), and lowest effort in 1974 (349 striped marlin

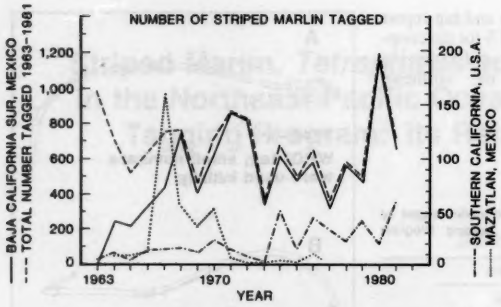


Figure 2.—Distribution of tagging effort, by year, for striped marlin off Mazatlán, Baja California Sur, and southern California, 1963-81.

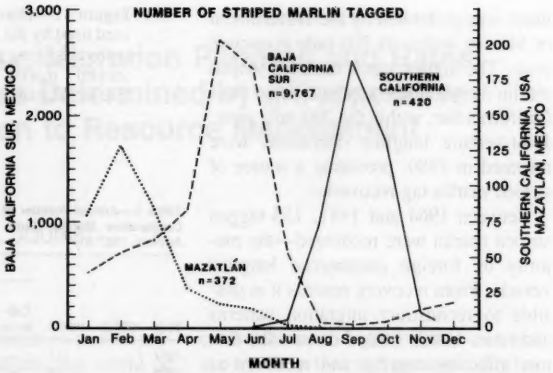


Figure 3.—Distribution of NMFS tagging effort, by month for tagging off Mazatlan, Baja California Sur, and southern California, 1963-81.

tagged); average tagging rate for 1963-81 was 668 striped marlin per year.

Distribution of tagging effort for the three major areas of tagging is given in Figures 2 and 3. Tagging effort increased off Mazatlán and Baja California Sur, Mex., in the middle 1960's. Through 1981, tagging effort levels ranged from 350 to 1,200 fish per year for Baja California Sur, and 30-80 fish for southern California.

The tagging program is a cooperative one and is dependent upon the active support of the anglers. Thus tagging frequency can fluctuate greatly, depending upon fishing success; tagging will be maximum during the peak of the fishing season and during seasons having better than average catches, and tagging will tend to be centered in specific geographical areas. Tagging of striped marlin in the northeast Pacific during any one year is not distributed randomly in time. High catch rate periods are evident for each of the three tagging areas. Figure 3 illustrates the timing of the releases for each of the three major tagging areas. The timing of tagging off Mazatlán and southern California is directly related to striped marlin availability occurring only during specific months. Striped marlin are available about the southern tip of Baja California Sur during most months of the year; however, because of a climate of high temperatures and humidity during the mid-summer through the fall there is much less fishing effort, and therefore less tagging.

There was little opportunity to recover tagged striped marlin in the eastern Pacific before the early 1960's. Prior to that time the Japanese longline fishery was expanding into the eastern Pacific, but the fishery had not yet concentrated in the northeast Pacific for the specific purpose of fishing striped marlin, sailfish, and swordfish. The recreational fishery continued to develop in the northeast Pacific but with a lower total estimated catch compared with current catches of an estimated 4,000-6,000 striped marlin per year. With the establishment in the early 1960's of an active commercial longline fishery in the northeast Pacific, the opportunity to recover tagged billfish increased (Ueyanagi, 1974). The Japanese longline fishery has recorded catches in the eastern Pacific (east of long. 130°W) of from 40,000 to 338,000 striped marlin annually during 1962-81. In 1963, the Japanese longline fishery for striped marlin, operating off the Baja California Sur peninsula (the major area of tagging), increased substantially and remained at a high level of effort until early 1977; catches from this area averaged about 30,000 striped marlin a year (Anonymous, 1962-80).

Recovery Rates of Tag Types

Of the striped marlin reported tagged during 1968-81, 12,689, 155 tags were returned for an overall return rate of 1.2 percent. The highest annual recovery rate was recorded in 1967—a 2.8 percent rate of recovery for 750 striped marlin tagged. The 1970 fishery (703 fish) yielded the second highest recovery rate—2.3 percent. These higher rates were recorded using FM67 tags. The recovery rate of the all-plastic double-barbed FM67 tag was 1.6 percent for 4,236 tags used. For 5,325 FH69 ("H" type) tags used, the recovery rate was 1.0 percent. A 38 percent greater tag return rate occurred with the FM67 tag compared with the FH69 tag.

Release and tag recovery data are given in Table 2. The foreign commercial longline fleet has provided 77 percent of the striped marlin tag recoveries for the NMFS program, billfish anglers have accounted for 16 percent, and the remainder (7 percent) have come from either other types of commercial fishing boats or tags washed ashore.

Considerable variation in recovery rate by year was observed between tag types. Table 3 gives the total number of recoveries by year and tag types for 1963-81. Table 4 gives striped marlin tag recovery rates by year tagged and by the two major tag types used by NMFS—FM67 and FH69.

Angler Estimated Weight Data

The angler, upon tagging a billfish, is asked to record the estimated length and weight of the tagged striped marlin on the

Table 2.—Striped marlin tagging and recapture data, 1963-81.

Tagging data					Recapture data		
Year	SWFC no.	Location[1]	Tagger	Date	Vessel or person	Distance[2] and direction from pt. of tagging	Days to recapture
1963	1	B	R. Fisher	6/6/63	Matsumoto maru #2	1,153/S	71
1964	2	E	G. Daley	2/24/64	Tosui maru #10	510/NW	59
1964	3	B	G. Myette	2/10/64	Okiya maru #8	162/SE	82
1964	4	B	B. Wilson	2/10/64	Seisho maru #11	140/SSE	56
1964	5	B	D. Cox	5/2/64	Kyowa maru #2	90/SSE	14
1964	6	B	C. Herrguth	5/26/64	Fukukyu maru #5	257/S	91
1964	7	A	C. Brignell	10/6/64	Kyowa maru #2	668/SE	26
1964	8	A	J. Koons	10/20/64	(Japanese longliner)	621/SE	34
1964	9	A	M. Freis	9/19/64	(Japanese longliner)	688/SE	87
1964	10	B	B. Hehr	2/7/64	(Japanese longliner)	320/SSW	154
1964	11	B	Unknown	~3/15/64	Gemini/W. Kalayjiah	3/SE	40
1965	12	B	H. Chappell	3/1/65	Unknown (Mexican boat)	0 n.mi.	13
1965	13	B	J. Kott	6/10/65	Hakuyo maru #28	108/S	47
1965	14	B	C. Brignall	6/25/65	Shoei maru #7	116/NE	46
1965	16	B	R. Fredman	5/19/65	Bunyo maru #1	210/NW	82
1965	18	B	B. Nicholes	5/18/65	Syoei maru #12	361/S	64
1965	19	A	J. Mathiesen	9/6/65	Fujisei maru #3	560/SE	59
1966	20	B	R. Switzer	4/29/66	Keifuku maru #3	155/SE	13
1966	21	B	P. MacMahon	5/6/66	Keifuku maru #3	190/SE	6
1966	22	B	R. Farley	3/15/66	Keifuku maru #3	198/SE	61
1966	23	B	E. Spainard	5/3/66	Keifuku maru #3	186/SE	17
1966	24	B	O. Spainard	5/4/66	Keifuku maru #3	224/SE	19
1966	25	B	T. Munteen	3/27/66	Keifuku maru #3	226/SE	67
1966	26	B	Unknown	~5/15/66	Syoei maru #7	138/S	110e[3]
1966	27	D	G. Heimpel	3/10/66	Syoei maru #7	252/W	146
1966	28	B	F. Bennett	4/14/66	(Sportboat) P. Testa	21/ESE	63
1966	30	B	P. Mackliz	5/6/66	Kyowa maru #2	161/SW	199
1966	31	B	N. Schwinn	4/7/66	Kyowa maru #2	63/S	225
1966	32	B	Unknown	Unknown	Kyowa maru #2	70/S	
1966	40	B	C. Hopton	4/15/66	Keifuku maru #7	100/NW	483
1967	34	B	H. Fink	6/9/67	(Sportboat) J. Ross	64/SW	18
1967	36	B	Unknown	2/13/67	Kaime maru #18	3,120/W	120
1967	37	B	J. Riberio	6/29/67	Koan maru #18	260/S	55
1967	38	D	G. Lyons	1/10/67	Keifuku maru #7	172/W	239
1967	39	D	L. Nelson	2/14/67	Keifuku maru #7	226/SW	213
1967	41	D	J. Sax	3/11/67	Kyowa maru #2	111/SW	45
1967	42	B	E. Horn	3/25/67	Kyowa maru #2	155/SE	30
1967	43	D	W. Milan	1/18/67	Kyowa maru #2	232/W	101
1967	44	D	M. Mernick	3/9/67	Kyowa maru #2	210/W	40
1967	45	D	K. Blacker	3/9/67	Kyowa maru #2	103/W	91
1967	46	D	H. Fait	6/21/67	Kyowa maru #2	233/W	28
1967	47	D	R. Daniels	3/3/67	Kyowa maru #2	276/W	206
1967	48	B	H. Ness	9/25/67	Kyowa maru #2	212/S	111
1967	49	D	B. Heimpel	7/14/67	Dyowa maru #2	169/W	88
1967	50	C	J. Binney	8/18/67	Dyowa maru #2	380/S	46
1967	51	D	Unknown	2/2/67	Kyowa maru #2	130/SW	93
1967	53	B	Unknown	~4/15/67	Shiyouei maru #12	280/S	150e
1967	54	B	Unknown	~4/10/67	Shiyouei maru #12	290/S	150e
1967	56	B	Unknown	Unknown	Sportboat/W. Werner, 2/2/68	Appx. same area	
1967	62	A	B. Devere	9/9/67	Kensei maru #26	2,090/WSW	179
1967	64	D	M. Olivetti	2/14/67	Syoei maru #12	285/SW	514
1968	57	B	J. McAieer	1/16/68	Anei maru #3	155/SE	27
1968	59	B	Unknown	Unknown	Anna Belle/T. Locke	<10 n.mi.	
1968	61	B	G. Knudsen	3/16/68	Syoei maru #7	75/E	75
1968	65	B	R. Honeycutt	3/7/68	Chokyu maru #12	278/SW	183
1968	66	B	J. Warren	6/28/68	Hokucho maru #18	140/SW	65
1968	67	B	B. Enyart	4/26/68	Huckucho maru #18	241/S	166
1968	68	B	J. McTee	3/25/68	Fuku maru #8	374/SE	133
1968	70	B	R. Fansett	6/30/68	Fuku maru #8	366/S	40
1968	71	B	J. McDonald	7/22/68	Genkai maru #18	125/NW	43
1968	72	B	J. Grigsby	6/13/68	Genkai maru #18	285/SW	95
1968	73	A	D. Daley	10/5/68	(Beach)/R. Armstrong	70/SE	
1969	75	B	B. Constantine	2/27/69	Sportboat/R. Jensen	12/N	1
1969	79	B	R. Taylor	2/2/69	(Japanese longliner)	285/SW	147
1969	80	B	L. Griffin	5/5/69	(Beach)/V. Wares	<20 n.mi.	
1969	81	B	D. Sansome	2/11/69	Chokyu maru #12	81/NE	157
1969	108	B	P. McVay	12/29/69	Chokyu maru #12	156/SE	5
1969	119	D	Unknown	4/21/69	Shoei maru #38	13/W	22
1970	82	D	B. Heimpel	1/13/70	Chokyu maru #12	32/S	5
1970	87	B	J. Smith	3/1/70	Keifuku maru #7	120/E	20
1970	91	B	R. Hodgden	2/5/70	Fukuju maru #18	98/E	20
1970	93	B	R. Fadem	3/5/70	Keifuku maru #7	53/NNW	74
1970	94	B	C. Errega	5/28/70	Fukuju maru #18	195/S	36
1970	99	B	B. Ashby	1/22/70	Charter boat/T. Schiltz	210/E	57
1970	100	Unk.	D. Stone	Unknown	Shoei maru #12		
1970	101	B	Unknown	3/70e	Kyowa maru #2	180/S	40e
1970	103	A	R. Naftzger	8/2/70	(Beach)/D. Mullis	60/SE	
1970	104	B	W. Marcusson	6/16/70	Azuma maru #31	120/SW	49
1970	105	B	G. Robinson	5/26/70	Chokyu maru #15	60/S	135
1970	106	B	R. von Ottow	2/9/70	Chokyu maru #15	95/NW	225

Continued on next page.

Table 3.—Recapture of striped marlin by year and tag.

	Recovery by ← tag type					
Year	A	FT-1	FM67	FH69(H)	Total	Percent recovery
1963	1				1	0.1
1964	1	4	5		10	1.4
1965	1		5		6	1.1
1966		2	11		13	2.1
1967		1	20		21	2.8
1968			12		12	1.4
1969			6		6	1.3
1970		1	15		16	2.3
1971			1	1	2	0.2
1972				6	6	0.7
1973				2	2	0.6
1974				8	8	1.2
1975				4	4	0.8
1976				5	5	0.8
1977				3	3	0.8
1978				2	2	0.3
1979				3	3	0.6
1980				23	23	1.9
1981			1	11	12	1.7
Totals	3	8	76	68	153[1]	

[1]Total = 155 (2 recaptures not identifiable as to year tagged).

Table 4.—Striped marlin tag recapture rates by year and tag (FM-67 and FH-69).

	FM 67			FH-69 ("H")		
Year	Tagged (no.)	Recaptured (no.)	Recaptured (%)	Tagged (no.)	Recaptured (no.)	Recaptured (%)
1963	9	0	0.0			
1964	232	5	2.15			
1965	200	5	2.50			
1966	370	11	2.97			
1967	683	18	2.53			
1968	818	10	1.22			
1969	450	6	1.33			
1970	646	14	2.16	1	0	
1971	639	1	0.01	194	1	0.05
1972	76	0		698	6	0.85
1973	8	0		334	2	0.59
1974	31	0		597	8	1.34
1975	7	0		481	2	0.41
1976	7	0		623	5	0.80
1977	5	0		347	3	0.86
1978				580	2	0.34
1979				500	3	0.60
1980				1,163	23	1.97
1981	1	1	100	701	10	1.42
Overall	4,236	71	1.57	5,325	55	1.03

tagging information card which is attached to the tag (Fig. 1). Because of their size and active nature, marlin caught by rod and reel are not removed from the water at the time of tagging, and thus only an estimate of weight is possible. Very few anglers gave estimates of length, although 96 percent of the tag cards included estimates of weights. The average estimated weight by year for

Table 2.—Continued.

Year	Tagging data: SWFC no.	Tagging data: Location[1]	Tagging data: Tagger	Tagging data: Date	Recapture data: Vessel or person	Recapture data: Distance[2] and direction from pt. of tagging	Recapture data: Days to recapture[3]
1970	107	B	J. Fiol	5/9/70	Shinko maru	70/E	152
1970	109	B	J. Recchardt	2/15/70	Chokyu maru #12	93/ESE	38
1970	110	B	C. Shattuck	3/20/70	Chokyu maru #12	125/SE	30
1970	111	D	B. Heimpel	Unknown	Chokyu maru #12	30/SW	
1970	115	B	K. Nefroney	3/18/70	Sportboat/W. Schreiner	110/NE	433
1971	117	B	G. Bruns	5/5/71	Gonei maru	213/NW	203
1971	118	A	H. Witherspoon	8/20/71	Kosho maru #11	675/SE	120
1972	121	B	J. Van Hove	4/22/72	Sportboat/A. Alvarez	<5 n.mi.	10
1972	126	B	W. Benson	5/1/72	Sportboat/G. Welton	70/SW	28
1972	138	B	A. Selby	5/19/72	Fukuju maru #32	95/SW	52
1972	139	B	T. Huls	6/2/72	Fukuju maru #32	240/NW	103
1972	197	B	R. Ayres	6/17/72	Keifuku maru #5	75/NW	670
1973	147	B	J. Birtcher	1/20/73	Kyowa maru #12	107/NE	64
1973	191	B	D. Rivoli	5/31/73	Kyowa maru #11	110/S	350
1974	187	B	Unknown	6/19/74	Chokyu maru #11	200/SW	11
1974	188	B	H. Shaw	5/27/74	Choyku maru #11	105/SE	10
1974	189	B	Unknown	1/26/74	Choyku maru #11	70/SE	124
1974	192	B	H. Moss	6/24/74	Kyowa maru #23	150/W	33
1974	193	B	Unknown	6/74	Kyowa maru #23	105/W	60e
1974	194	B	B. Guenter	6/3/74	Kyowa maru #23	50/NE	7
1974	195	B	F. Scroggs	6/8/74	Chokyu maru #12	50/E	20
1974	196	B	T. McConville	6/9/74	Keifuku maru #5	55/NW	30
1974	224	B	I. Lewis	5/13/74	Chokyu maru #25	340/S	194
1975	230	B	P. Sadkr	7/28/75	Sportboat/C. Taylor	180/SE	152
1975	263	B	C. Weiner	6/23/75	Sportboat/E. Landsaw	<5 n.mi.	987
1976	215	B	J. Carpenter	5/24/76	Keifuku maru #12	300/SW	112
1976	221	B	C. Bradfield	4/6/76	Kyowa maru #28	15/S	10
1976	225	B	Unknown	5/19/76	Chokyu maru #25	280/S	30
1976	229	B	A. Jensen	5/30/76	(Marlin on beach)	B/W	2
1976	247	A	E. Martin	11/11/76	Kotoshiro maru #15	2,520/S	80
1977	248	B	H. Consley	5/31/77	Sportboat/H. Sherman	3 n.mi.	7
1977	276	A	E. Martin	9/3/77	Sportboat/S. Nesbitt	35/E	398
1977	277	A	R. Barrett	10/12/77	Sportboat/C. Husfar	83/SE	358
1978	285	B	Unknown	6/78	El Indomable (tuna seiner)	60/SE	305
1978	306	B	F. Gilbert	12/30/78	Sportboat/L. Clinkenbeard	20/NE	475
1979	283	B	P. Locke	6/1/79	Fukuju maru #32	390/SW	81
1979	284	B	T. Sheehan	5/1/79	Fukuju maru #32	390/SW	81
1979	291	B	Unknown	4/79	Sportboat/J. Clarke	10/SE	<20
1980	299	B	W. Jossey	3/28/80	Horso maru #21	207/S	257
1980	300	B	J. Collins	12/2/80	Hosyo maru #21	110/S	13
1980	301	B	N. Ruston	3/15/80	Chidori #86	110/SSW	240
1980	302	B	A. Williamson	4/14/80	Chidori #86	120/SW	211
1980	303	B	J. Crowson	7/8/80	Chidori #86	240/W	160
1980	304	B	L. Schonert	10/14/80	Chidori #86	230/W	28
1980	305	B	S. Stevenson	5/20/80	Fukutoku maru #18	720/SE	148
1980	307	B	M. Bryant	6/9/80	(Commercial diveboat)	800/NW	130
1980	308	B	K. Johnson	5/9/80	Japanese longliner	80/SSW	90
1980	309	B	J. Cunningham	5/19/80	Japanese longliner	105/SSW	90
1980	314	B	J. Lee	6/30/80	Sportboat/M. Barks	70/SE	118
1980	315	B	S. Jacobson	4/9/80	Japanese longliner	250/S	189
1980	316	B	J. Brandes	4/9/80	Japanese longliner	300/S	180
1980	318	B	Unknown	7/15/80	Sportboat/M. Brett	<5 n.mi.	12
1980	319	B	Unknown	5/80	Sportboat/Unknown	<5 n.mi.	<10
1980	323	B	L. Wiczai	7/15/80	Hosyo maru #21	410/SW	411
1980	327	B	H. Kameron	4/2/80	Sportboat/E. Bishop	12/SW	352
1980	328	B	C. Ackerman	5/23/80	Sportboat/R. Fraser	60/S	301
1980	329	B	H. Kameon	7/17/80	Sportboat/E. Cohen	60/SW	205
1980	334	B	N. Yoshihara	5/6/80	Sportboat/A. Aguayo	180/SE	324
1980	342	B	R. Martin	6/13/80	Chidori #88	260/NW	553
1980	343	B	E. Clark	6/5/80	Chidori #88	260/NW	560
1980	344	B	T. Gillen	12/26/80	Chidori #7	240/S	337
1981	322	A	C. Herberts	8/30/81	Sportboat/B. Feldhorn	50/E	13
1981	324	B	Unknown	Unknown	Sportboat/E. Miller	<5 n.mi.	
1981	325	B	J. Brown	2/28/81	Sportboat/G. Carter	<5 n.mi.	38
1981	326	B	N. Braemer	4/4/81	Sportboat/F. Appling, Jr.	12/E	39
1981	330	B	P. Gillen	1/5/81	Sportboat/T. Gillen	20/E	5
1981	335	Unk.[4]	Unknown	Unknown	Korean longliner, 12/24/81		
1981	336	B	M. Abbott	12/26/81	Korean longliner	155/S	50
1981	337	B	P. Torre	6/15/81	Hosyo maru #21	360/S	183
1981	338	B	K. Defieore	10/23/81	Hosyo maru #21	240/NW	53
1981	339	B	E. Martin	11/30/81	Hosyo maru #21	241/NW	20
1981	340	B	D. Lyddon	7/2/81	Mosyo maru $21	360/S	166
1981	341	–	Unknown	Unknown	Hosyo maru #21		
1981	345	A	E. Martin	9/25/81	Fukujyu maru #32	600/SE	57
1981	346	B	W. Feldhorn	3/9/81	Fukujyu maru #32	30/W	210

[1]A = Southern California, B = Baja California Sur,
C = Guaymas-Kino area, D = Mazatlan, and E = Acapulco
[2]Distance is listed in nautical miles.
[3]e = estimate.
[4]Unk. = unknown.

Table 5.—Average estimated weight for striped marlin tagged off Mazatlan and Baja California Sur. Mexico and Southern California, U.S.A., by year as recorded on the tag card report. Weights in parentheses represent the yearly average weight of landed striped marlin as recorded by the Balboa Angling Club, Balboa, California, and the Marlin Club, San Diego, California.

Year	Mazatlán	Southern California		Baja California Sur,
1963		135.0	(132.8)	127.8
1964	145.0	127.8	(134.9)	150.6
1965	147.1	126.7	(141.6)	136.1
1966	125.7	131.9	(129.1)	149.1
1967	117.1	130.4	(128.4)	137.7
1968	127.7	143.8	(136.8)	148.0
1969	117.9	150.0	(146.3)	132.1
1970	101.2	115.4	(138.8)	133.7
1971	106.6	132.2	(144.6)	125.9
1972	135.0	142.9	(146.4)	131.5
1973	146.7	125.0	(149.1)	135.6
1974	140.0	133.4	(144.4)	138.4
1975	160.0	88.0	(151.7)	143.2
1976	159.9	139.1	(142.6)	154.8
1977		135.5	(153.2)	148.3
1978		140.3	(148.0)	150.6
1979		142.7	(145.6)	138.6
1980		135.5	(153.2)	133.9
1981		166.2		144.7

striped marlin tagged off southern California, Baja California Sur, and Mazatlán is given in Table 5.

Longline vessels sometimes submitted weight data on recaptured marlin and occasionally biological information. A total of 74 striped marlin recoveries had usable weight data. The weights from the commercial longline fishery were with the bill and portion of head removed at about the area of eye orbit, and less gills and internal organs. The reported or dressed weight must therefore be increased by a factor of 1.2 to give the approximate round weight of the fish.

I compared the estimated weights at tagging and their calculated weights at recovery within release time periods; the results are given in Figure 4. For a release time of 0-60 days, the average recovery weight of 31 marlin was 0.3 kg less than the initial weight estimated by the angler at tagging. Variation is extensive between tag and recovery weights for 0-60 days, ranging from an overestimate of 12.7 kg (28 pounds) to an underestimate of 19.0 kg (42 pounds). For recoveries made 61-120 days after release, the average recovery weight was 1.5 kg (3.3 pounds) less than had been estimated by the angler. Weight at recovery would be expected to increase as time of recovery increased. Average weight estimated at time of tagging compared with average

weight at recovery appears to show a positive growth increase for the recovery period 121-240 days after tagging. On Figure 4, only 44 percent of the recoveries (30 fish) showed an increase in weight and 56 percent (38 fish) were reported caught at weights less than estimated at tagging. Five recoveries (7 percent) indicated the same weight as tagged, some having release times of 1-2 years. These data indicate that angler estimated weight data lacks the precision necessary for striped marlin growth studies. Similar conclusions were made for black marlin resulting from our Coral Sea studies (Squire and Nielsen, 1983).

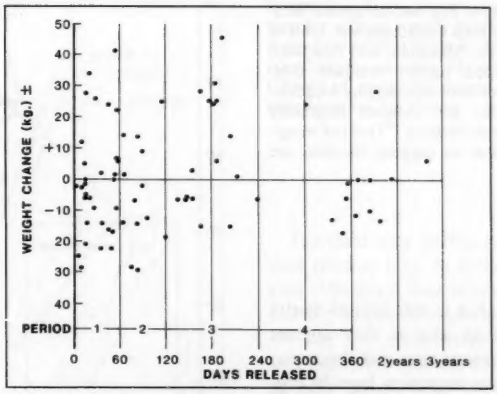


Figure 4.—Comparison of angler-estimated weights of striped marlin at tagging with weight at recovery, by release time and weight at recovery.

Migratory Patterns and Rates

The season and geographical locations of tagging must be considered in evaluating the migratory patterns and rates determined from tagging results. Striped marlin occur throughout the Pacific Ocean between about lat. 45°N to 35-40°S and are common to the tropical and temperate waters of the Pacific and Indian Oceans (Fig. 5). Based on longline catch data, the distributional pattern of this species in the Pacific is horseshoe-shaped with the base located along the central American coast (Nakamura, 1974). Striped marlin tagging in the northeast Pacific Ocean has been concentrated in two areas about the southern tip of Baja California: Off Cabo San Lucas and about 60 miles to the northeast off Bahia de Palmas in the Gulf of California (Fig. 5). Most of the striped marlin were tagged in the Bahia de Palmas area from April to August. Only a few striped marlin have been tagged in the Gulf of California north of Bahia de Palmas. Other areas of tagging were off Mazatlán from January through March, and off the southern California coast from August to October (Fig. 3).

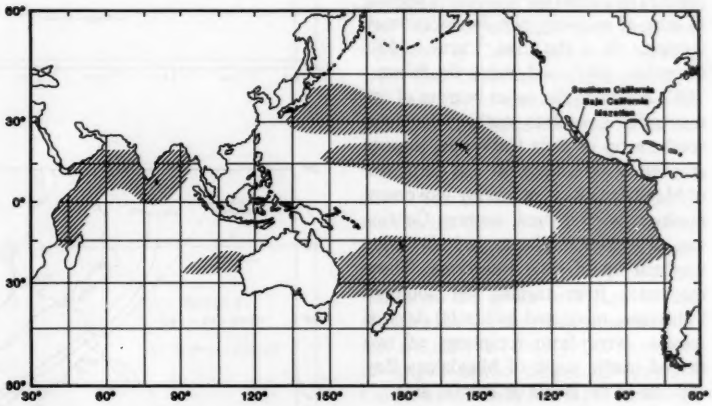


Figure 5.—Distribution of good fishing grounds for striped marlin, based on catch data from Japanese longline fishery during 1964-69 (from Nakamura, 1974).

Few long-range recoveries were made. Only two marlin tagged off Mexico were recovered more than 1,000 n.mi. from the point of tagging (1.3 percent of the recoveries). One recovery was made 1,560 n.mi. south of the Baja California peninsula; the other recovery was made about 200 n.mi. southwest of the Hawaiian Islands. For southern California tagging, the majority of recoveries were off or south of the Magdalena Bay area with two of the eleven recoveries greater than 2,000 n.mi. from the tagging point. Of the three marlin recovered off southern California, two were tagged off southern California about 1 year before recovery, and the other had been tagged about the tip of Baja California Sur 130 days before recovery.

Direction of Migration

Locations of tagging, recovery, and mean bearing direction in degrees (True) of recovery from point of tagging are given in Figures 6-9 for time-at-large periods 0-60 days, 61-120 days, 121-240 days, and 241 days-1 year for striped marlin tagged off Baja California Sur, and Mazatlán. Figure 10 gives tagging and recovery locations for striped marlin tagged off southern California. From the tag and recovery geographical plots in Figures 6-10 it appears that all migration is radiating outward from a geographically localized point of tagging, and that the tagging location is the "center" of dis-

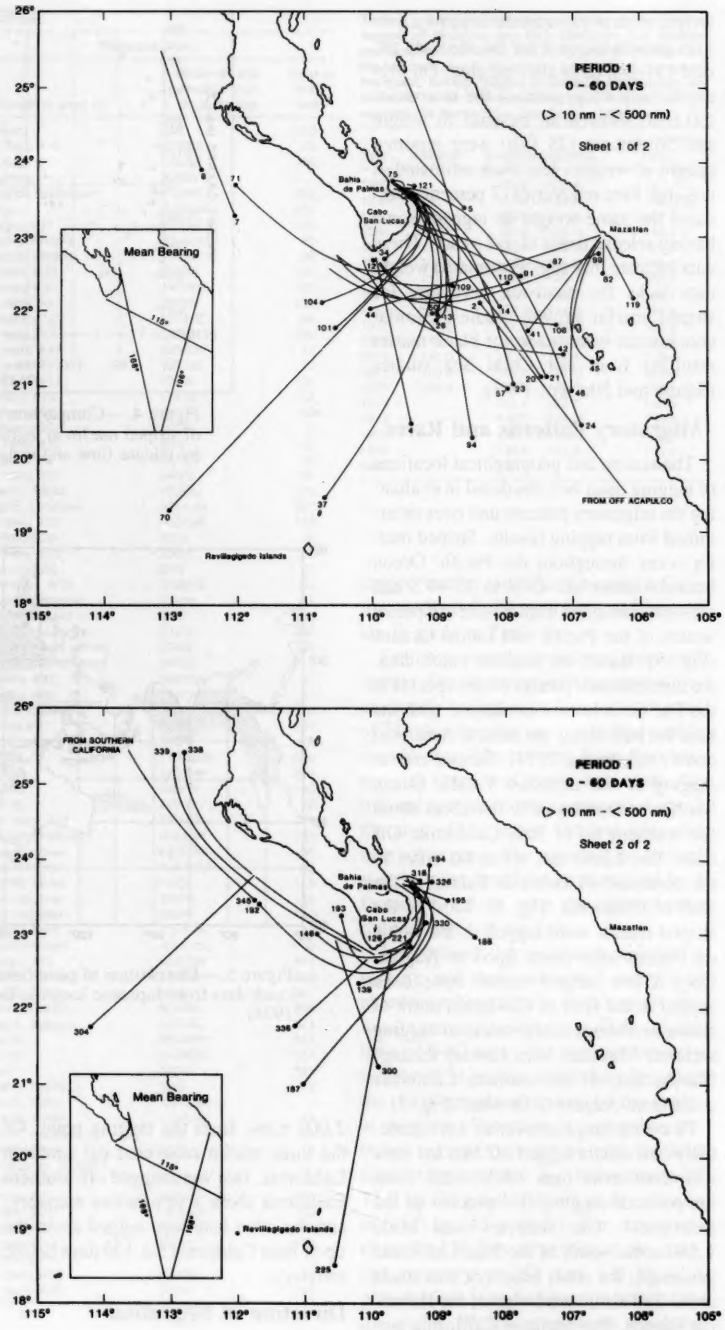


Figure 6.—Tag and recapture locations off Baja California Sur, Gulf of California, Mazatlán, and Acapulco for striped marlin released 0-60 days. Dot indicates tagging location. Line does not indicate migratory path. Mean bearing (°True) of recapture points to tagging location are shown.

tribution, which it is not. Striped marlin are tagged in an area as they migrate through it at various rates and directions. Numbers on the migration lines in Figures 6-10 indicate the NMFS Southwest Fisheries Center recovery number (Table 2).

For recoveries 0-60 days after tagging (Figure 6a, b) the mean bearing in degrees (True) from the location of tagging to area of recovery was for location of tagging off Cabo San Lucas, 115°, Mazatlán, 196°, and Bahia de Palmas, 168°. Although the mean bearing of tag recoveries is south to southeast from the southern tip of Baja California, several recoveries were made off and northwest of Magdalena Bay, indicating movement northwestward toward southern California, of striped marlin tagged about the southern tip of Baja California. Three recoveries from tagging off southern California, recovered within 60 days of release, were from recaptures of two striped marlin south of Magdalena Bay and one in the Bahia de Palmas area.

From 61 to 120 days after release (Fig. 7), most recoveries of striped marlin tagged near Cabo San Lucas and Bahia de Palmas were made to the south and southwest of Cabo San Lucas, generally in an area southwest of those recoveries observed with 60 days of release. Mean bearing for locations of tagging in relation to recovery points were for Cabo San Lucas, 182°, Mazatlán, 243°, and Bahia de Palmas, 201°. Some evidence of migration from the Bahia de Palmas/Cabo San Lucas area around the tip of Baja California was evidenced by four recoveries made south of Magdalena Bay. During the 61 to 120 day period after release two recoveries were made south of Magdalena Bay for striped marlin tagged off southern California.

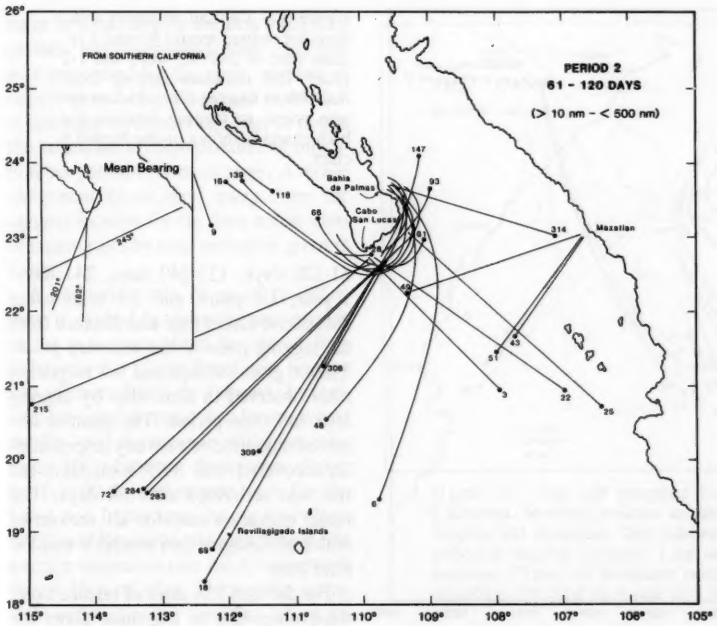


Figure 7.—Tag and recapture location for striped marlin having a release time of 61-120 days. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location are shown.

The third time period (121-240 days after release) (Fig. 8) includes the mid-year (180 days) time of release. In considering an annual migration pattern, the 180-day time period could be important as it marks the time the fish might reach its most distant point from the tagging location. The mean bearing direction of recovery points in relation to tagging locations about the tip of Baja California again was shifted to the southwest. Mean bearing directions from tagging off Cabo San Lucas was 212° and Bahia de Palmas 196°. Five striped marlin were recovered northwest of Cabo San Lucas, between Cabo San Lucas and Magdalena Bay. The majority of recoveries were further southwest than those observed for the 61-120 day period.

Recoveries for release times of 241 days-1 year and for 1-2 years (Fig. 9a, b) were in the same area as those observed for the first two time periods. Recoveries of striped marlin tagged off southern California are given in Figure 10 and show a southern migration from the summer and early fall fishery. For recoveries of striped marlin tagged off southern California the mean bearing of recoveries 0-60 days was 153°. For the 61-120 days release time the recovery locations were 161°.

Rates of Migration

The average migration rate in nautical miles per day (n.mi./day) away from the location of tagging was calculated for the same time-at-large periods 0-60 days,

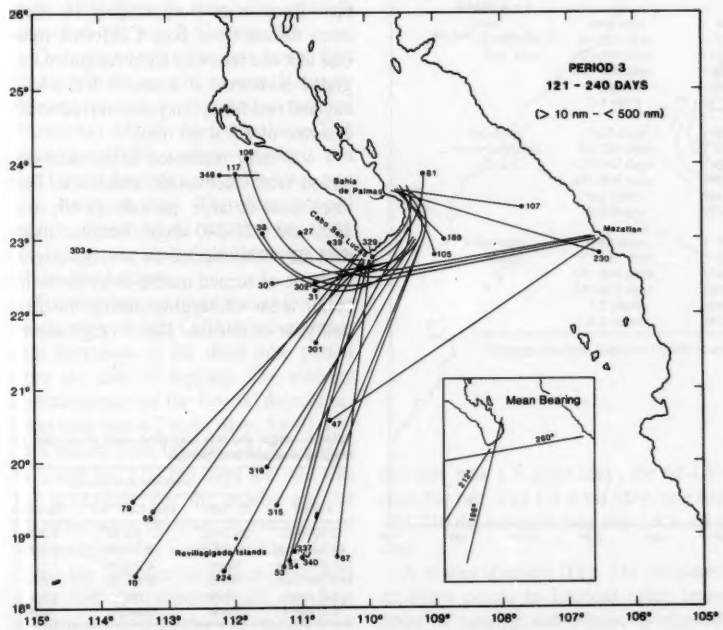
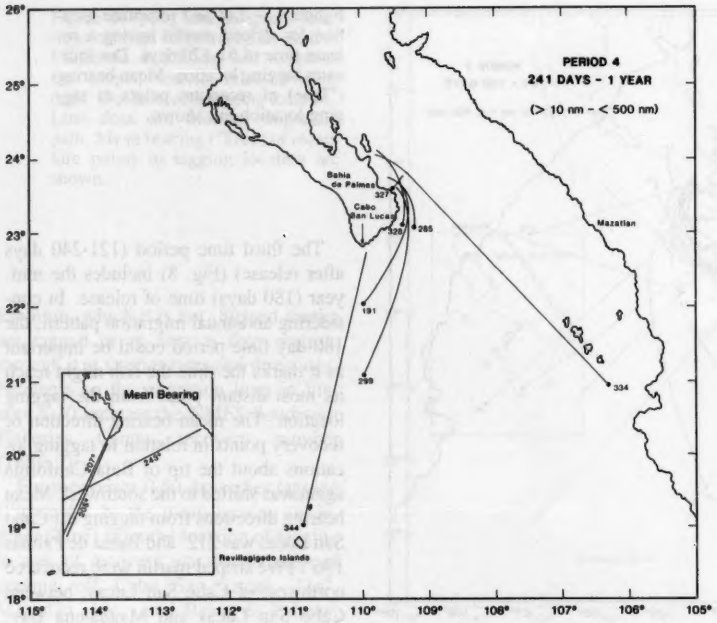


Figure 8.—Tag and recapture locations for striped marlin having a release time of 121-240 days. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location are shown.



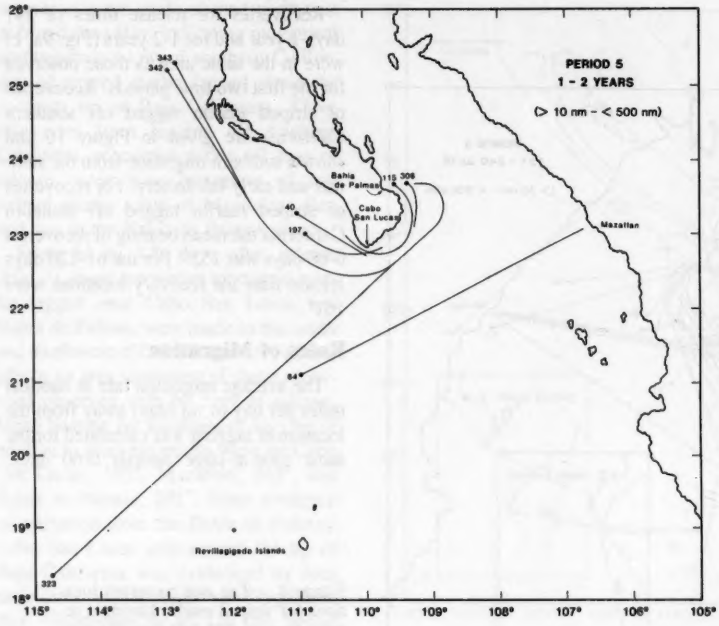


Figure 9.—Tag and recapture locations for striped marlin having a release time of 241-365 days and 1-2 years. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location for both charts is shown on the Period 5 chart.

61-120 days, 121-240 days, 241 days-1 year, 1-2 years, and 2-3 years using data derived from time and distance from the tagging point to the recovery point. Table 6 gives the high and low migration rates observed in n.mi./day by tagging area and time period. The greatest observed migration rate for any striped marlin recovered was 31.5 n.mi./day; the fish was recovered after 80 days. The mean migration rate for all recoveries with time/distance data available was 1.6 n.mi./day.

For the first 120 days of release time, the average rate of migration about the southern tip of Baja California is much lower than the average rate of migration observed for fish tagged off southern California. Recoveries from southern California tagging recovered to the southeast or south averaged 13.3 n.mi./day. Recoveries from tagging in other areas distant from Baja California indicate that one recovery from Acapulco migrated northwest at a rate of 8.6 n.mi./day and one from Guaymas moved south at a rate of 8.3 n.mi./day.

I was most interested in the data obtained from recoveries within the first three time-at-large periods (0-60, 61-120, and 121-240 days) because these data may better define the average migration rate of striped marlin away from the major areas of tagging during the first half year of release. The average move-

Table 6.—High and low migration rates (n.mi./day) by tagging area and time period.

Period	High/low in n.mi./day		
	S. Calif.	Baja Calif. Sur	Mazatlán
0-60 days	25.7/9.5	31.2/0.42	8.3/2.5
61-120 days	31.5/5.6	26.0/0.59	2.3/1.4
121-240 days	None	6.2/0.28	1.7/1.1
241-365 days	None	0.8/0.03	None
1-2 years	10.09	1.0/0.5	10/0.1
2-3 years	None	10.0/0.1	None

ment in n.mi./day for the first three time periods was determined; then each rate was multiplied by the mean number of days within each time period in relation to zero day or date of tagging, to obtain the estimated average distance of migration per period of time-at-large. Average movement (n.mi./day) away from the tagging location for the three major areas of tagging and by time periods is given in Table 7.

A migration rate (n.mi./day) difference is evident between tagging periods in the two areas about the tip of Baja California Sur (Cabo San Lucas tip area and offshore Bahia de Palmas). I examined time and distance data for recovered marlin for differences in migration rates (n.mi./day) between these areas during the first 60 days of release time. For the Cabo San Lucas area during the winter months of November through March, the average migration rate for 13 recaptures was 4.45 n.mi./day. During the spring and early summer months of April through June, the average migration rate for 5 recaptures was 5.18 n.mi./day. For the Bahia de Palmas area, only one sample was available during the winter months of November through March. Twenty-seven recoveries were available from April through June. The average migration rate was 2.53 n.mi./day.

The average migration rate for the first 60 days for the eastern tip area (Bahia de Palmas) for both time periods combined (November-March, April-June) was 2.54 n.mi./day; off the southern tip area (Cabo San Lucas) for both time periods the rate was 4.6 n.mi./day. Therefore, striped marlin appear to be moving at about twice the rate in the southern tip area (Cabo San Lucas).

The average rate of migration from the southern tip of Baja California Sur peninsula decreases in the third time period from the date of tagging. The average migration rate for the first 60 days of release time was 4.2 n.mi./day, for 61-120 days release time the rate was 4.3 n.mi./day, and for 121-240 days the rate was 1.4 n.mi./day. For the nearby area of Mazatlán some decrease in average nautical miles per day was also evident; however, the average migration rate was about half that observed off the Baja peninsula. For 0-60 days of release time the rate was 1.9 n.mi./day, for 61-120 days the rate was 1.4 n.mi./day, and for 121-240 days the rate was also 1.4 n.mi./day.

A scatter diagram (Fig. 11) compares recovery points in nautical miles from point of tagging and release to elapsed time in days from release for recoveries made within the first 240 days of release time from tagging off Baja California Sur. For marlin recovered more than 240 days after release about the Baja California Sur peninsula, the average distance from the tagging point to the recovery

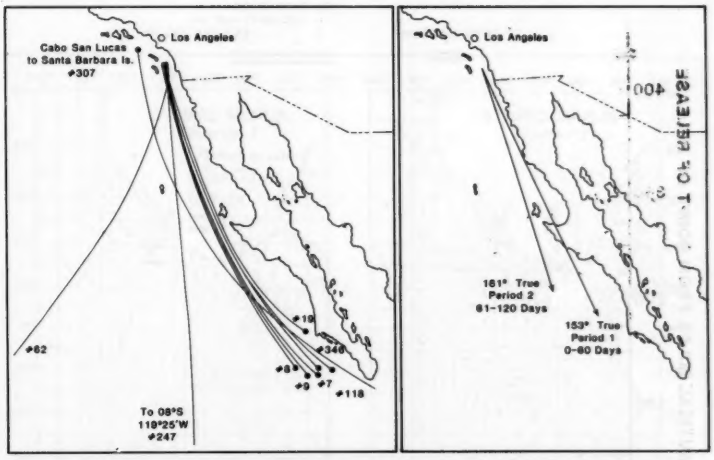


Figure 10.—Tag and recapture locations for marlin tagged off southern California. Numbers indicate month of tagging and number of days between tagging and recapture. Dot indicates recapture location and origin of line indicated tagging location. Line does not indicate migratory path. Mean bearings (°True) of recapture points to tagging locations are shown for recaptures for 0-60 days and 61-120 days.

Table 7.—Average movement away from the tagging location in nautical miles per day for each area, by time periods[1].

Area	Period	(Midpoint time in days)	No. in samples	Average n.mi./day	Period midpoint (n.mi.)
Baja, California Sur, Mex.	0-60 days	(30)	49	4.2	126
	61-120 days	(91)	23	4.3	391
	121-240 days	(181)	28	1.4	253
	241-365 days	(303)	7	0.4	121
	1-2 years	(547)	7	0.3	52
	2-3 years	(912)	1	0.01	9.1
Southern California, U.S.A.	0-60 days	(30)	6	11.3	339
	61-120 days	(91)	2	16.0	1,456
	121-240 days	(181)	1	11.7	2,117
	241-365 days	(303)	1	0.2	61
	1-2 years	(547)	1	0.1	55
	2-3 years	(912)	0		
Mazatlán, Mexico	0-60 days	(30)	9	1.8	54
	61-120 days	(91)	3	1.9	173
	121-240 days	(181)	1	1.3	235
	241-365 days	(303)	0		
	1-2 years	(547)	1	0.6	328
	2-3 years	(912)	0		

[1]Recaptures from Acapulco (1) and Guaymas (1) averaged 8.64 and 8.26 n.mi. per day.

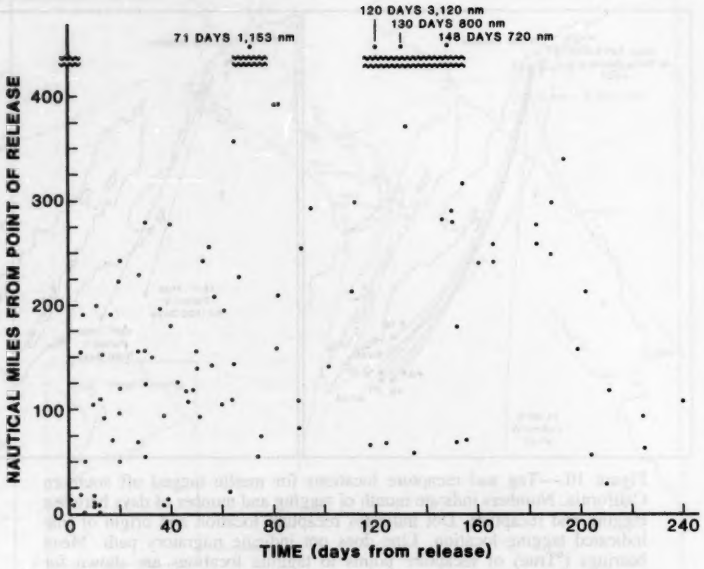


Figure 11.—Scatter diagram for first 240 days of release time for striped marlin tagged about Baja California Sur.

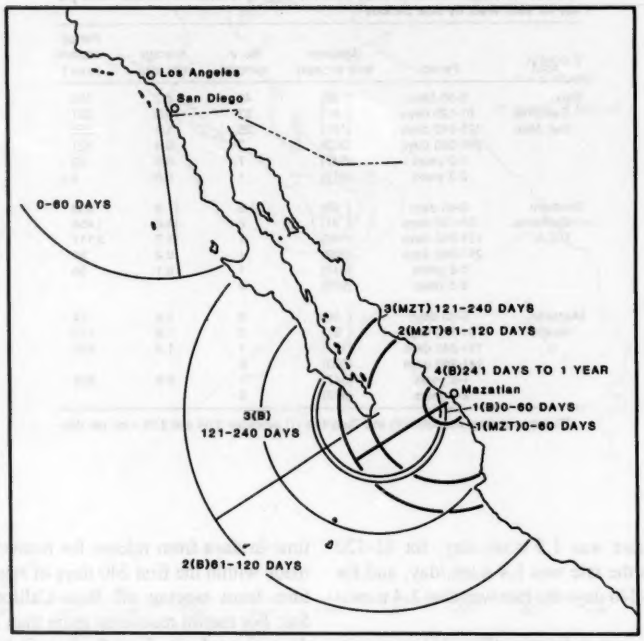


Figure 12.—Midpoint migration distances for time periods, tagging to recapture, 0-60 days, 61-120 days, and 121-240 days.

point was, for 241 days-1 year, 119 n.mi. (high, 207 n.mi., low, 12 n.mi.); for the 1-2 year period, 172 n.mi. (high, 410 n.mi., low, 20 n.mi.); and 5 n.mi. for the single recovery made 2-3 years after tagging.

Arcs showing average mileage limits for four time periods (0-60, 61-120, 121-240 and 241-360 days) for Baja California Sur recoveries were plotted (Fig. 12), using the average distance traveled from tagging to recovery per day by time period (average n.mi. per day times the midpoint for each time period).

Results would indicate a more rapid movement away from the southern tip of Baja California for marlin tagged during the late spring and early summer and during the 0-120 day period than for the following 121-240 day period. Long-term recoveries of one or more years were made in the area from Cabo San Lucas to the Revillagigedo Islands indicating that the striped marlin either remained in the area, or returned to it.

Discussion

Factors Related to and Affecting Tagging and Recovery

Tagging of large pelagics such as billfish cannot be done in large numbers, unlike with the smaller pelagics such as tuna. Also, it is difficult to obtain sufficient numbers of billfish to tag and release other than in areas having a productive rod-and-reel recreational fishery. In attempting to determine the general migrating pattern of billfish, data collected in other biological, physical oceanography, and catch analysis studies may be useful in developing a hypothesis to describe a migration pattern.

For a more ideal program to better define seasonal migration patterns, as an aid in determining stock boundaries, tagging effort should be distributed throughout the range of the species. For the migration patterns of striped marlin, tagging should be conducted in the northeast and southwest Pacific, central north Pacific, off Ecuador and around Galapagos Island, and in an area about 400 n.mi. west of Peru. The tagging effort reported here is from one portion of the striped marlin's distributional range—the northeast Pacific.

Tag Recoveries in the Eastern Pacific in Relation to the Geographical Distribution of the Longline Fishing Effort

The amount of fishing effort varies in the geographical areas fished by commercial longline, and these changes may affect the number of recoveries and recovery location. Data describing the catch and effort patterns for black marlin by the Japanese longline fishery operating off Queensland, Australia, have been useful in estimating migration patterns for black marlin in the southwest Pacific (Squire and Nielsen, 1983). Longline catch and effort data covering all the major oceans are published annually by the Research Department of the Japan Fisheries Agency, and these data are grouped by 5° longitude by 5° latitude areas and include results for striped marlin fishing.

From 1965 to 1975, striped marlin catch rates for the Japanese longline fishery in many areas of the northeast Pacific averaged 2.1 to 5.1 or more striped marlin per 1,000 hooks effective hooking effort (Suzuki and Honma[1]); maximum catch rates in the Pacific Ocean were recorded near the tagging area off the Baja California peninsula. Figure 13 outlines for 1956-70 (from Joseph et al., 1974) the average level of Japanese longline striped marlin catch per thousand hooks fished in the eastern Pacific. The effectiveness index (E) of the effort on striped marlin (effective hooks/nominal hooks) has exceeded 1.0 in the eastern Pacific since 1964 indicating "targeting" on striped marlin resources (Suzuki and Honma[1]).

Figure 14 illustrates the distribution of Japanese longline effort in the eastern Pacific at intervals of 5 years during which the tagging was conducted. Hook effort is distributed at levels of 1-2 million or more hooks per year per 5° longitude by 5° latitude area south and west of the tagging area in the equatorial area from about lat. 10°N to lat. 15°S. High

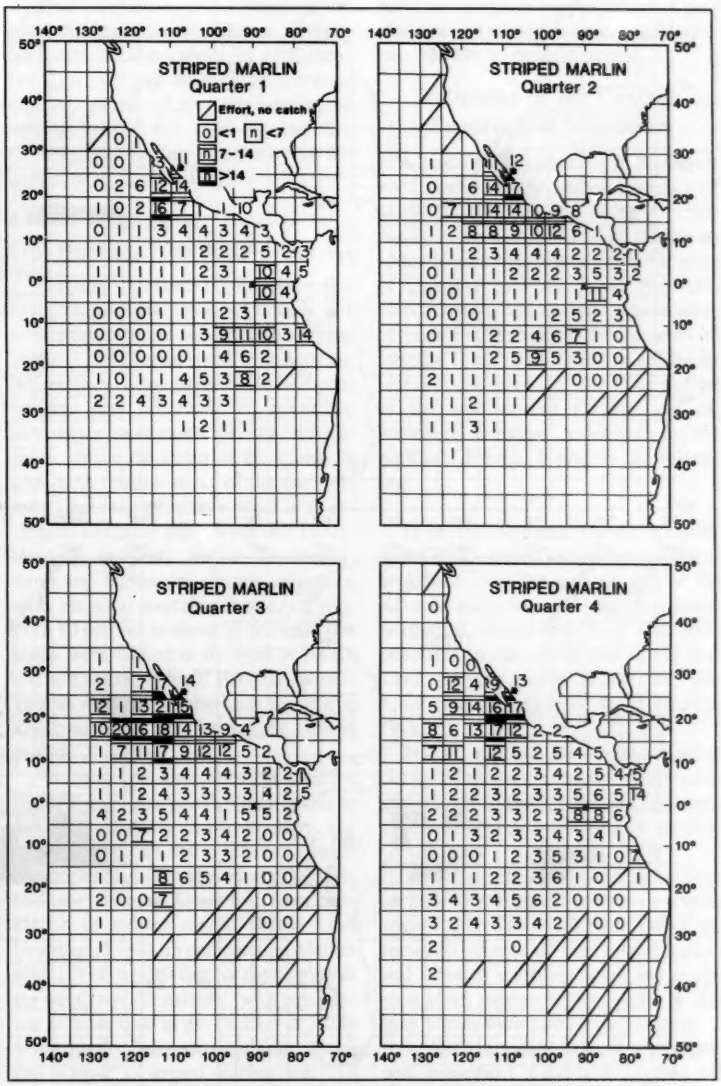


Figure 13.—Average number of striped marlin caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-70 and by 5° areas (from Joseph et al., 1974).

(1-2 million hooks) effort levels have been recorded 1,200 n.mi. southwest to 1,500 n.mi. west of the tagging area. In addition to the high hook effort near the area of tagging, these other areas of high effort provide possible recovery points for striped marlin that migrate toward more distant waters.

Relationship of Tagging Results to Spawning

Presumably striped marlin spawn be-

[1]Suzuki, Z., and Misao Honma. 1977. Stock assessment of billfishes in the Pacific. Billfish stock assessment workshop, Honolulu, HI, 5-16 December 1977. Unpubl. working pap., 129 p.

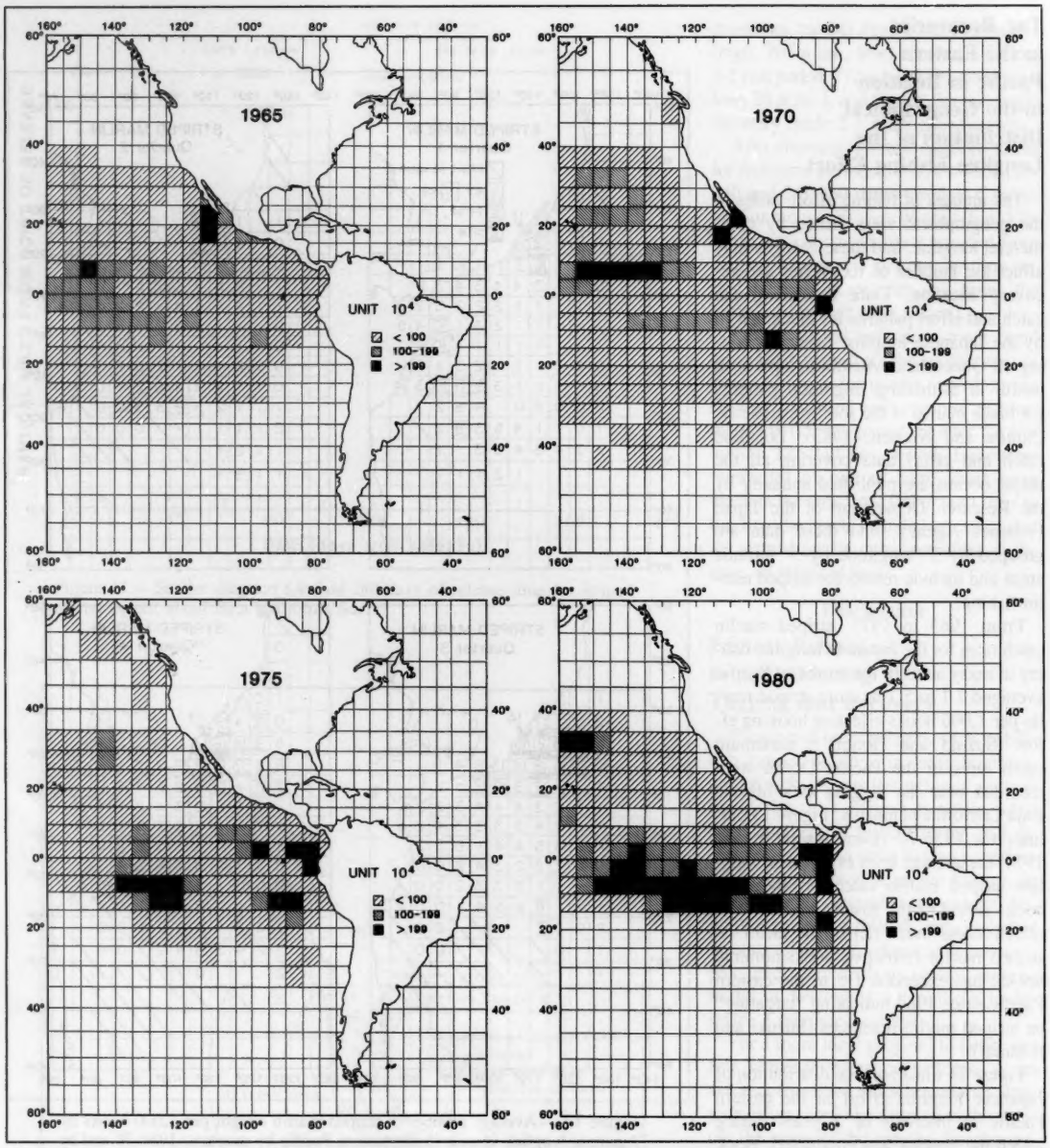


Figure 14.—Distribution of estimated total fishing effort in hook number for Japanese longline operations in the eastern Pacific.

tween June and October in the offshore areas of the northeast Pacific, south and southwest of Cabo San Lucas in the area of the Revillagigedo Islands (Joseph et al., 1974; Shoki[2]). Maturity is reached at about 160 cm (eye-fork length) based on gonad indices (Kume and Joseph, 1969).

Japanese longline data for 1967 through 1975 (Suzuki and Honma[1]) indicates that in the northeast Pacific (10° × 130°W) the greatest numbers of fish were caught in the 160-170 cm eye-fork length range.

[2]Shoki, G. A., Manzanillo, Mex., 1965. Personal commun.

Longline records taken in 1983-84 for striped marlin caught by joint-venture operations in the area about Baja California indicate the maximum number of fish in the 165-170 cm eye-fork length range. Both sets of data show a large catch under the 160-165 cm length range; therefore, the population of striped marlin in the reported spawning area southwest of Baja California would appear to be composed of a mixture of immature and mature fish.

Off Mazatlán, tagging was conducted primarily during late winter and spring months, before the predicted spawning in the northeast Pacific. Also, maximum tagging effort was conducted around the tip of Baja California Sur, in late spring and early summer before and at the beginning of the predicted spawning in the northeast Pacific. Developing gonads have been noted about the tip of Baja California Sur in June and July (J. Squire, personal observ.). However, they were not approaching the high gonad index levels of near-spawning as observed several hundred miles to the south or southwest from samples provided by Japanese longline vessels.

Tagging off southern California was done in the late summer and early fall during the predicted spawning period in the area southwest of the tip of the Baja California peninsula. Sampling of striped marlin off southern California in summer and early fall showed little gonad development (gonad indices <1.0) (Eldridge and Wares, 1974). Observations of gonad development, suggest that possibly half of the tagging of striped marlin about the southern tip of Baja California may be on the immature or prespawning segment of the population. The prespawners move offshore south and southwest of Cabo San Lucas toward a spawning or feeding area.

Physical Environment Relative to Migration

Hanamoto (1974), describing longline fishing conditions in the "target" areas off Mexico, noted the movement of the fishery for striped marlin in relation to a shift in thermocline depth. He reported that the pattern of expansion and contraction of the shallow-water thermocline area of about 30.5 m (100 feet) in depth along Mexico's mainland and Baja California coast coincided with the pattern of seasonal expansion and contraction of good fishing grounds. Figure 15 is a composite of illustrations by Hanamoto (1974) which give the monthly distribution of mean relative abundance of striped marlin for 1966-70 and the monthly thermocline topography of the northeastern tropical Pacific.

Effects of Tagging and Hooking Mortality

Mortality of striped marlin as a result of the tagging process is not known. All marlin tagged were subjected to varying amounts of sublethal stress from hooking before they were tagged. Stress from hooking may not result in immediate mortality in most cases but may, in some cases, reduce the ability of the animal to cope with routine stress of the environment, and may ultimately result in an increased mortality rate (Wydoski, 1977). Hooking mortality studies on anadromous and freshwater species indicate a wide range of mortality levels, ranging from 10 percent to about 25 percent. The levels were related to the type of hooks and bait used in fishing. Hooking mortality plus natural mortality may result in a lower survival rate for tagged striped marlin.

No tag returns have been obtained for fish >3 years at large. This may be due to increased mortality due to hooking, tag loss, and the fact that a relatively small number of tags (average number tagged, 668/year) is being diluted by a large population of striped marlin (Bartoo and Ueyanagi, 1980). In comparison, Mather et al. (1974) reports that for the tagging in the western north Atlantic (with tags similar to those used in the Pacific) of 2,039 white marlin, *Tetrapturus albidus*, a species similar to striped marlin, and 216 tagged blue marlin, *Makaira nigricans*, 70 white marlin and one blue marlin were recovered. The recovery rates were 3.4 percent for white marlin and 0.4 percent for blue marlin. The population estimate for white marlin in the northwest Atlantic is considerably smaller than the population estimate for striped marlin in the Pacific (Shomura, 1980; Zuboy[3]). Higher recovery rates than those for striped marlin in the northeast Pacific, such as those observed for black marlin in the southwest Pacific (2.3 percent) and for white marlin in the Atlantic (3.4 percent) may be related to lower tag dilution rate, relative to population size.

Estimates of the Central Tendency of Migration

A tentative hypothesis can be developed describing the central tendency of migration direction and rate for striped marlin in the northeast Pacific. Using information derived from the graphic plots of tag and recovery points, the migration direction and rate analysis, movements of high CPUE areas in the commercial longline fishery over time, the geographical distribution of longline fishery effort in the total eastern Pacific, and the spawning behavior exhibited in the northeast Pacific, I suggest the following:

1) In the northeast Pacific areas of high CPUE, striped marlin move south or southwest from the tagging area in the summer and early fall and then move northward toward the Baja California peninsula in the winter and spring seasons. Tagging results parallel the seasonal catch distribution of the longline fleet.

2) The seasonal shift of thermocline depth in relation to catch distribution changes are similar to the seasonal geographical changes observed in longline CPUE rates.

3) Movement of striped marlin from an area of low gonad indices or a nonspawning area about the tip of Baja California to an area of high gonad indices and reported spawning south and southwest gives support to the results of tagging which show similar movements.

4) Recovery data indicate a predominate movement south from tagging off southern California, and the data indicate that some marlin from about the tip of Baja California Sur migrate northwest to off southern California.

5) Because few (5 or 3.2 percent) of the total recovered marlin were caught at

[3]Zuboy, J. R. 1977. Atlantic billfish stock assessment. Billfish Technical Workshop, Honolulu, HI, 5-19 December 1977. Working pap. QP-2, 36 p., unpubl.

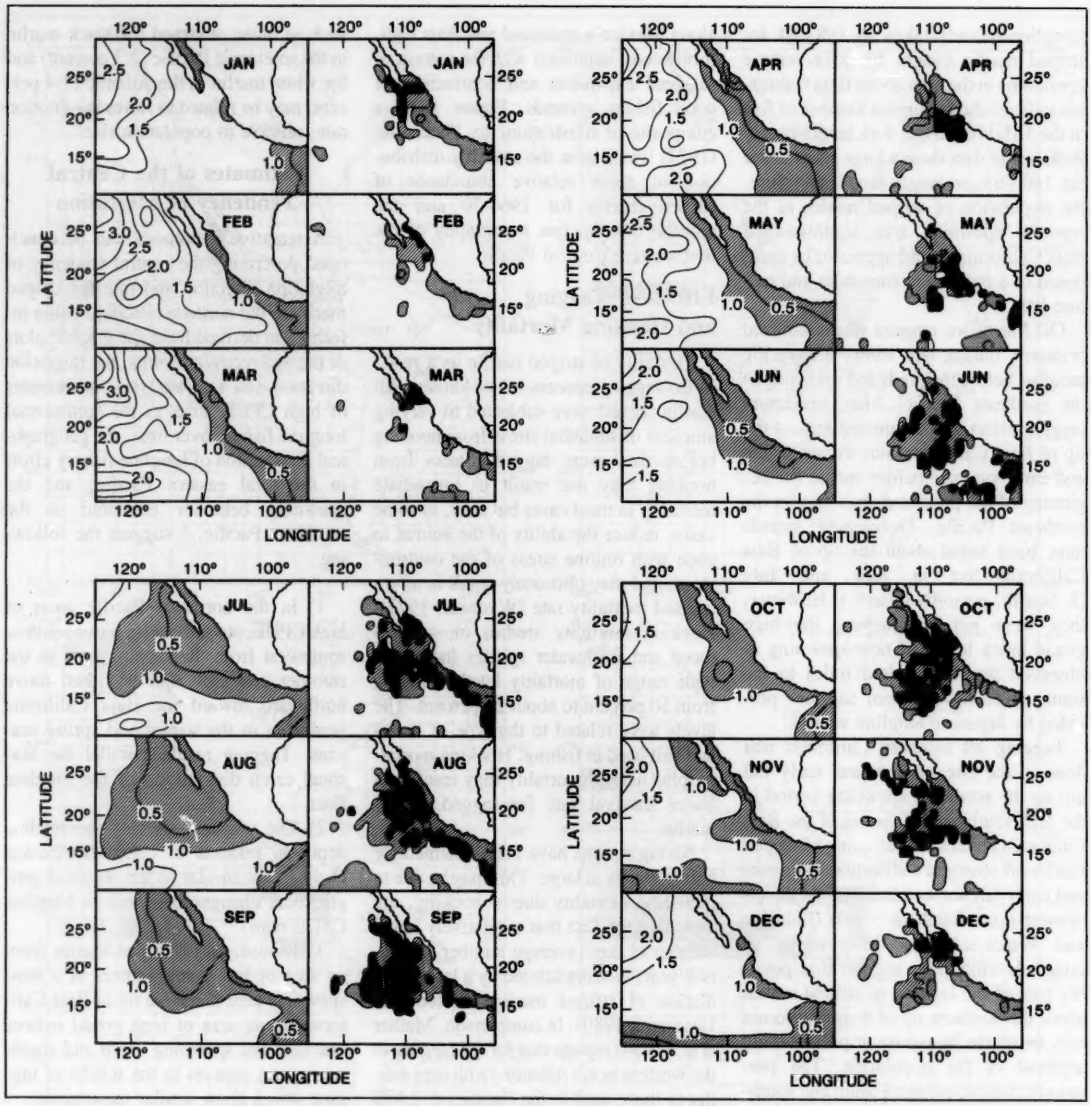


Figure 15.—Monthly distribution of mean relative abundance of striped marlin and monthly thermocline topography for fishing areas off Mexico, 1966-70. Numbers on the contour line represent the depth to the top of the thermocline in hundreds of feet. Areas of relative abundance are: high abundance (>1.5 percent), dark areas; medium abundance (1.4 to 0.5 percent), hatched areas; low abundance (>0.5 percent), strippled areas (from Hanamoto, 1974).

a distance greater than 800 n.mi. from the point of tagging, striped marlin cannot be considered short-term distant-water migrators in the Pacific, like bluefin tuna, *Thunnus thynnus*, and albacore, *Thunnus alalunga*.

The migration of striped marlin in the northeastern Pacific area of tagging and of the commercial longline fishery can be hypothesized from the results of tagging (Fig. 16). The tagging results indicate

that the migratory rates and patterns of striped marlin are highly variable. There is, however, a central tendency of movement of tagged striped marlin which is similar to the shifts in CPUE; the movement of tagged fish is also patterned by biological and environmental factors that occur in the tagging and fishing area.

The recreational rod-and-reel fishery that has tagged and released striped marlin off Baja California is fishing on the same population as the commercial longline fleet operating about the tip of Baja California, as the recreational fishery and the commercial longline fishery and the recreational fishery catch-per-unit-effort (CPUE) exhibited a coefficient of correlation of $r_2 = 0.82$ (Squire, 1982). The relation of migratory patterns of striped marlin tagged in the northeast Pacific to striped marlin resources common to other geographical areas is unclear. However, the fluctuations and the downward trend of the commercial longline catch rate for areas about the southern tip of Baja California (lat. 20°N × long. 109°W and 105°W) appears to be similar to other areas in the eastern Pacific (Fig. 17). Throughout most of the remaining eastern Pacific striped marlin is not a target species for the longline fishery, and catches are incidental to catches of tuna and other species of billfish. The similarity of catch rate trends (Fig. 17) indicate that there is a relationship between the population of striped marlin that is being subjected to targeting off Mexico (25-28 percent of the eastern Pacific catch) and to striped marlin common to other areas of the eastern Pacific.

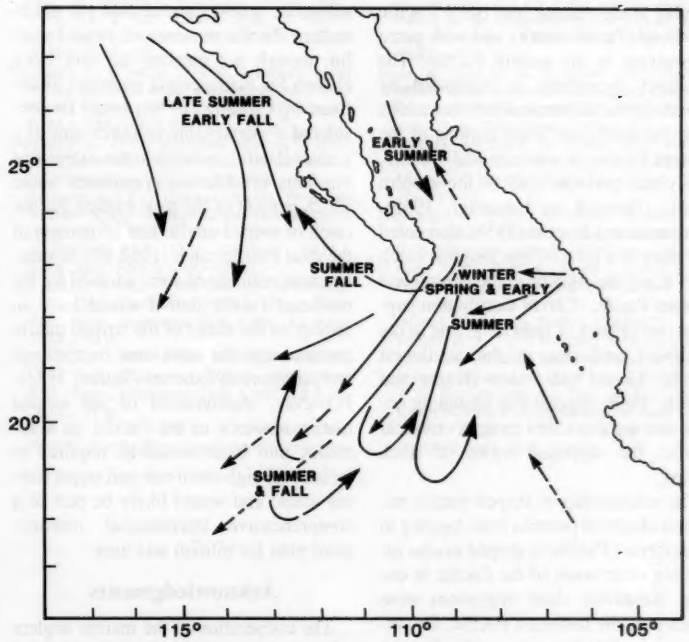


Figure 16.—Hypothetical striped marlin migration patterns for the northeast Pacific.

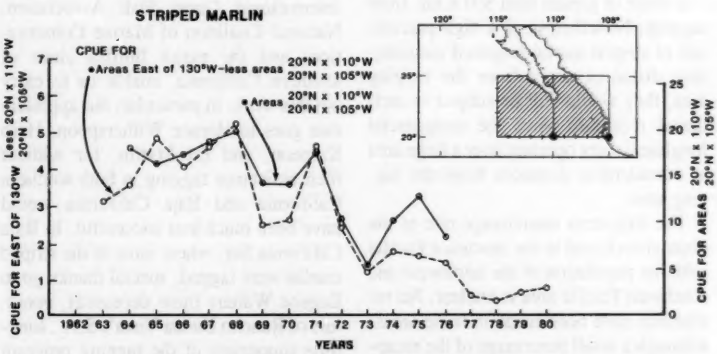

STRIPED MARLIN
CPUE FOR
•Areas East of 130°W-less areas 20°N x 110°W 20°N x 105°W
•Areas 20°N x 110°W 20°N x 105°W
CPUE FOR EAST OF 130°W Less 20°N x 110°W 20°N x 105°W
CPUE FOR AREAS 20°N x 110°W 20°N x 105°W
1962 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
YEARS

Figure 17.—Fluctuations in the Japanese longline CPUE for two 5° areas off Baja California, and the CPUE for the eastern Pacific (E of long. 130°W) less the two 5° areas.

Relation of the Findings to Management

One of the primary purposes of this tagging program is to provide data for management decisions relative to the resource stock structure of striped marlin. The stock structure of striped marlin is not fully understood; also, if any striped marlin substocks exist they have not yet been identified.

Three possible stock structure hypotheses have been proposed for striped marlin in the Pacific. At the 1977 Billfish Stock Assessment Workshop in Honolulu, Hawaii, Suzuki and Honma[1] suggested a northwest, southwest, and eastern Pacific stock division, based on biological and catch distribution evidence. The two other stock structure hypotheses which were believed most tenable at that time (Shomura, 1980) were: 1) A single-unit stock in the Pacific. This hypothesis is supported by the continuous distribution of striped marlin in a horseshoe-shaped pattern. 2) A two-stock structure, with the stocks separated

roughly at the equator into North Pacific and South Pacific stocks and with some intermixing in the eastern Pacific. The two-stock hypothesis is supported by morphometric differences between adults from the north and south regions of the western Pacific (Kamimura and Honma, 1958) and perhaps also in the eastern Pacific (Howard an Ueyanagi, 1965). Kamimura and Honma (1958) also noted that there is a zone of low longline catch rates along the equator in the central and western Pacific. Larval distribution suggests two centers of spawning, one in the northwest and one in the southwest Pacific. Gonad index data (Kume and Joseph, 1969) suggest that spawning occurs throughout the eastern tropical Pacific, the supposed region of stock mixing.

The relationship of striped marlin migration observed patterns from tagging in the northeast Pacific to striped marlin inhabiting other areas of the Pacific is unclear. Relatively short migrations were common in the northeast Pacific; few recaptures in distant areas would indicate a minimum of mixing. Long-range movements over time are possible; however, only 3.2 percent of the recoveries were at a distance of greater than 800 n.mi. from tagging. Nonetheless, if a high percentage of striped marlin migrated considerable distances away from the tagging area, they would still be subject to incidental recapture since the commercial longline fishery operates over a large area at considerable distances from the tagging area.

The long-term interchange rate of the population found in the northeast Pacific with the population of the northwest and southwest Pacific area is unclear. No recaptures have been made in these areas, although a small percentage of the recaptured fish was headed in those directions, which indicates that some population interchange could be expected over time. Therefore, defining the various populations of these areas as "unit stocks" as required for stock assessment methods (Cushing, 1970) may be academic in the case of striped marlin.

The results of this migration study, when combined with other information developed from studies of striped marlin biology, fishery dynamics, and catch distribution, would indicate that the northeastern Pacific resource of striped marlin, though not meeting the unit stock criteria for management purposes as defined by Cushing (1970), could be considered a manageable resource unit of a greater Pacific resource to the extent that this area off Mexico contributes about 25-28 percent of the total eastern Pacific catch of striped marlin and 14 percent of the total Pacific catch (1962-80). If management regulations were adopted for the northeast Pacific unit if would have an impact on the status of the striped marlin resource and the associated recreational and commercial fisheries (Squire, 1982). However, management of the striped marlin resource in the Pacific on a resource unit basis would be required to include all high catch rate and target fishing areas, and would likely be part of a comprehensive international management plan for billfish and tuna.

Acknowledgments

The cooperation of the marine anglers who caught, tagged, and released striped marlin made this study possible. Their support and willingness to participate and the support of such organizations as the International Game Fish Association, National Coalition of Marine Conservation, and the major billfish clubs of southern California, enable us to carry out this work. In particular, our appreciation goes to Horace Witherspoon, Herb Kameon, and Ed Martin, for without their assistance tagging in both southern California and Baja California would have been much less successful. In Baja California Sur, where most of the striped marlin were tagged, special thanks go to Eugene Walters (now deceased), operators of Rancho Buena Vista[4], S.A., longtime supporters of the tagging program and other scientific studies in the Baja area, and to the current staff of Rancho Buena Vista, Ted Bonney, Mark Walters, and the fishing captains, and to the captain tagging and releasing the most striped marlin in the eastern Pacific, Jesus Ariza Ruiz. Others in the Baja California Sur area have given outstanding support: These include Jorge Excudero, Bob Van Wormer, Bud Parr, and most of the charter boat operators about the tip of Baja. Without the cooperation of these individuals, and the U.S. sportfishing boats that frequently fish and tag in the Baja area, in addition to tagging off southern California, increased knowledge of the oceanic migration patterns of billfish would not be possible.

Recaptures of tagged fish are just as important as tagging, and we wish to convey our appreciation to the Japanese and Korean commercial longline fleet captains and crews and to the marine anglers who recaptured tagged marlin and returned the tags. Guillermo Adachi of Manzanillo and Mario Comparan of Ensenada, Mex., have been of assistance through contacts with the Japanese longline operations off Mexico. The Japan Fisheries Agency, Far Seas Fishery Research Laboratory, Shimizu, Japan, has also been instrumental in returning tags from striped marlin recaptures by the Japanese fleet, and these important efforts are appreciated.

[4]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

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Relation of Sea Surface Temperature Changes During the 1983 El Niño to the Geographical Distribution of Some Important Recreational Pelagic Species and Their Catch Temperature Parameters

JAMES L. SQUIRE

Introduction

In the coastal areas of the northeast Pacific, the distribution and apparent abundance of many species are affected more by environmental changes, as reflected in changes of sea surface temperature (SST), than by the catches in commercial and recreational fisheries. Natural fluctuations in marine populations resulting from changes in the physical and biological environment are known to significantly affect the determination of stock status and the level of catches (Sette, 1961; Ahlstrom, 1961, 1967; Anonymous, 1960; Uda, 1957, 1961; Miller, 1956; Jensen, 1930). Environmental changes such as small changes in SST either above or below the long-term mean significantly affect production by west coast pelagic fisheries. Continued periods of below normal temperatures in the late 1940's contributed to the decline of the Pacific sardine, *Sardinops sagax*, and are believed to have contributed to the abundance of the northern anchovy, *Engraulis mordax*, which was dominant from the mid-1950's to mid 1970's (Anonymous 1960; Sette, 1961, 1969).

The reasons for the extensive northward movement of marine fishes during abnormally warm periods are not well understood. However, these movements appear to be related to changes in the total environment (physical and biological) and reflect the requirements of the animals to sustain life. The interactions between the physical and biological environments are very complex, and the effects of changes in most physical and biological characteristics on the behavior and distribution of marine fishes is little known. Sea surface temperature, one of the more easily measured physical environmental characteristics has been shown to have a positive correlation with the distribution of pelagic fish (Radovich, 1961; Hubbs, 1948).

Periods of unusually warm sea surface temperatures were reported along the northeast Pacific coast for 1859, 1926, 1931, 1941, 1957-58, 1972-73, 1976, and 1982-83. These periods, which are popularly called "El Niño" result from intense warming in the eastern tropical Pacific. This warming results from changes in the near-surface meteorology and oceanography, which in turn are related to a global shift in upper air pressure patterns. Previously, the most intense warm period after the record setting warm period of 1926 was in 1957-1958; however, the 1982-1983 warm period also appeared to be intense, exceeding that of 1957-1958 and possibly equaling that of 1926. The magnitude and duration of positive temperature anomalies observed off southern California during the warm periods of 1957-1958, 1972-1973, 1976-1977, and 1982-1983 are shown in Figure 1.

Warm periods appear to benefit the southern California fisheries for such subtropical species as the yellowtail, *Seriola lalandei*; Pacific barracuda, *Sphyraena argentea*; and Pacific bonito, *Sarda chiliensis*. The southern California recreational fishery also benefits from the northward migration of several other subtropical and tropical species, such as skipjack tuna, *Euthynnus pelamis*; yellowfin tuna, *Thunnus albacares*; and dolphin, *Coryphaena hippurus* (Radovich, 1960; Squire, 1983). Very warm temperatures may also have had a negative effect, as was evidenced during 1957-1958 and 1972-1973 by reductions of albacore, *Thunnus alalunga*, in the California recreational catch and of northern anchovy in the commercial and recreational bait fisheries. Off central California to Washington, catches during warm periods have been reduced in the troll fisheries for species of chinook salmon, *Oncorhynchus tshawytscha*; and coho salmon, *O. kisutch*.

Environmental changes, as reflected in SST changes, may be positive (above-normal SST's, or positive anomalies) or negative (below-normal water temperatures, or negative anomalies). The effects of prolonged high positive anomalies on the distribution of marine fishes off the west coast were well documented by Walford (1931), Radovich (1960, 1961, 1975), Ketchen (1956), Hubbs and Schultz (1929), Hubbs (1948), Bell and Pruter (1958), Royal and Tully (1961), and Fluharty (1984). Because of the impact of prolonged and strong positive temperature anomalies on the southern California catch of pelagic species having centers of distribution off Mexico, short-term intense warming periods have

James L. Squire is with the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, 8604 La Jolla Shores Drive, La Jolla, CA 92038.

also been synonymous with better fishing—particularly off southern California and less so off central and northern California.

The period of above-normal SST's in 1982-83 resulted in some unusual migrations of tropical and subtropical fishes and invertebrates into northern latitudes more commonly occupied by subarctic species. An important factor in the northerly movement of species from tropical and subtropical areas is the timing and intensity of the higher temperatures (Fig. 1). Though temperatures increased, giving positive anomalies off southern California starting in July 1982, positive anomalies remained only about 2°F (1.1°C) above normal until December 1982, when this margin increased to about 4°F (2.2°C). The distribution and occurrence of species off southern California changed little during the period of slightly above-normal temperatures in summer and fall 1982, although Blesser (1984) noted an increase in catch of Pacific bonito. By January 1983, extensive effects on the changes in seasonality of billfishes off southern California were evident. Swordfish, *Xiphias gladius*, remained very abundant through January 1983 (an unusual condition), and good commercial catches were being made by drift gillnets when the season closed on 1 February, 1983. Striped marlin, *Tetrapturus audax*, were observed near Tanner Bank (west of San Clemente Island) in January 1983, although past catch records for southern California showed no catch of striped marlin in December or later. Early in 1983, red crabs, *Pleuroncodes planipes*, were abundant in the waters and on the beaches of southern California, indicating an increased development of the northeasterly coastal countercurrent (the Davidson Current), which in turn resulted in the northward movement of more-southerly forms of pelagic invertebrates. The strong countercurrent indicated that changing oceanographic conditions accompanied the positive temperature anomalies, resulting in more favorable conditions for the catch of tropical and subtropical pelagic species off southern California and northward.

The persistence of the 1983 warm period along the west coast is important.

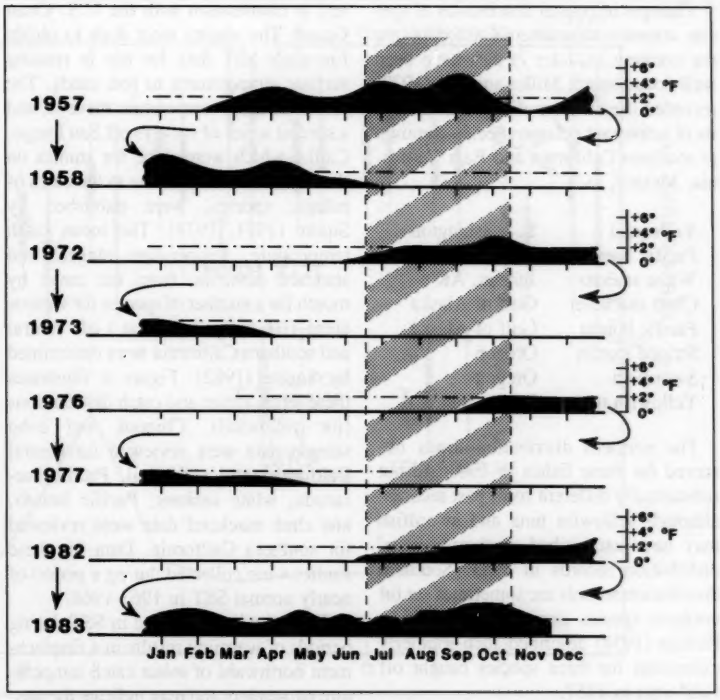

Figure 1.—Positive anomalies in SST's observed off southern California during the warm periods of 1957-58, 1972-73, 1976-77, and 1982-83. Striped area represents the major catch period off southern California, for yellowtail, Pacific barracuda, Pacific bonito, white seabass, chub mackerel, yellowfin tuna, and striped marlin.

Although positive temperature anomalies were not as high as in 1957, they lasted longer: 15 months (September 1982-November 1983) of positive anomalies 2°F (1.1°C) or more off southern California led to environmental changes that in turn resulted in significant changes in west coast recreational and commercial fisheries and in the geographical distribution of the fishery resources.

In 1983 several important southern California recreational and commercial species were reported much farther north than normal.[1] Most recent reports (Fluharty, 1984) give the following northernmost distributions in 1983.

Yellowtail, *Seriola lalandei*: Port Orford, OR.

Pacific barracuda, *Sphyraena argentea*: Ketchikan, AK and Uyak Bay, Kodiak Isl. AK.

White seabass *Atractoscion nobilis*: Westport, WA.

Chub mackerel, *Scomber japonicus*: Oregon, Washington, into southern part of Puget Sound and north to Queen Charlotte Isl., B. C., Can.

Pacific bonito, *Sarda chiliensis*: Klawock, AK (Prince of Wales Isl.) (unverified rep. Kodiak Isl., AK).

Swordfish, *Xiphias gladius*: S. of Vancouver Isl., landed Flores Isl., B. C., Can.

Striped marlin, *Tetrapturus audax*: Off Monterey Bay and San Francisco area.

Yellowfin tuna, *Thunnus albacares*: Avila to Morro Bay, CA (reported from Monterey Bay, CA).

[1]Fluharty, D., S. Crooke, and J. Fulton. Seattle, Wash. Personal commun.

Changes in coastal distribution of species common to southern California into the northern latitudes in past have been well documented. Miller and Lea (1972) recorded the northern distributional limits of important pelagic species common to southern California and Baja California, Mexico, as:

Yellowtail	S. Washington
Pacific barracuda	Kodiak Isl., AK
White seabass	Juneau, AK
Chub mackerel	Gulf of Alaska
Pacific bonito	Gulf of Alaska
Striped marlin	Oregon
Swordfish	Oregon
Yellowfin tuna	Pt. Buchon, CA

The northern distribution limits observed for these fishes in 1983 are not substantially different form past records, although yellowfin tuna and swordfish may have established northern coastal distribution records in 1983. Southern distribution records are sometimes set for northern species during warm periods; Phillips (1958) described such southerly extensions for three species caught off California in 1957.

Most literature on the effects of the warm period on fish catch involves descriptions of the geographical extent of distribution. Some west coast researchers have reviewed the catch of fish off California in relation to variable sea surface temperature, and others the effects of temperature changes in northern waters to catch (Radovich, 1960, 1961; Hubbs, 1948; Ketchen, 1956; Bell and Pruter, 1958.) Here I present information on mean sea surface temperatures at the point of capture ("catch temperatures") that have been observed for several species common to southern California recreational fisheries, and on the geographical extension of these optimal catch temperatures into the northern latitudes off the west coast during the 1983 period of intense warming.

Materials and Methods

In 1963 monthly studies of coastal sea surface temperatures by airborne infrared surveys were started by the Tiburon Marine Laboratory (now the Tiburon Laboratory of the National Marine Fisheries Service, Southwest Fisheries Center) in cooperation with the U.S. Coast Guard. The studies were done to obtain fine-scale SST data for use in relating surface temperatures to fish catch. The results of these temperature surveys, and a special series of surveys off San Diego, Calif., which were done for studies on the relation of temperature to the catch of pelagic species, were published by Squire (1971, 1978). The mean catch temperature, temperature ranges, and standard deviation from the mean by month for a number of species for various areas (10′ long. × 10′ lat.) off central and southern California were determined by Squire (1982). Figure 2 illustrates these temperature and catch distributions (for yellowtail). Chinook and coho salmon data were reviewed for central California, and yellowtail, Pacific barracuda, white seabass, Pacific bonito, and chub mackerel data were reviewed for southern California. Data for these studies were collected during a period of nearly normal SST in 1963-1968.

The latitudinal increase in SST during periods of warming results in a displacement northward of mean catch temperature parameters and may indicate the possible extent of a parallel northward displacement of these species. From published catch-temperature data (Squire, 1982) and unpublished observations, I developed data on mean catch temperatures for several pelagic species off southern California, for salmon off central California, and for two oceanic pelagic species (striped marlin and yellowfin tuna) that are frequently caught off southern California in summer. I have also compiled the monthly mean ($\bar{x}$ct) and standard deviation about the mean ($\bar{x}$); high mean (H$\bar{x}$ct), and low mean (L$\bar{x}$ct) catch temperatures and the range of temperatures at which these species were observed (Table 1). I examined SST charts produced semimonthly during 1983 by the Inter-American Tropical Tuna Commission and the National Weather Service and noted the geographical extent of mean catch temperatures for each time period. Throughout the area south of the most northward geographical extension of the low mean catch temperatures (Fig. 3-7 and 9), all sea surface temperatures equaled or exceeded the low mean catch temperature.

Results

Observations of the changes in mean catch temperatures in relation to SST changes off the U.S. west coast are reviewed separately here for various coastal pelagic species.

Yellowtail

The pelagic coastal migratory yellowtail commonly ranges from the southern tip of Baja California, Mex. to near Point Conception, Calif. It is one of the most important recreational fishes in southern California and an important recreational and commercial species in Mexico. The major sport fishing areas at the northern end of the range are the Coronado Islands, Mex., and kelp beds off San Diego and Catalina Island, Calif. Yellowtail are caught off sourthern California in large numbers only during their summer northward migration from Baja California and are rarely caught north of Point Conception except during years of anomalous warm SST's.

The mean catch temperature for yellowtail caught off southern California was 63.2°F (17.3°C) with a standard deviation of ±3.6°F (2.0°C). The low mean catch temperature of 57°F (13.9°C) was recorded during March and the high mean catch temperature of 70.0°F (21.1°C) during August; the total catch in March was only 2 percent of that in August. The range of temperatures at which yellowtail were observed to be caught off southern California was 51.0°-74.0°F (10.6°-23.3°C).

The shift of the warmer SST environment northward during summer 1983 was presumably responsible for the taking of yellowtail north of Point Conception; catches were also reported as far north as Port Orford, Oreg., In August 1983. Figure 3 illustrates for semimonthly periods from 16 April to 30 November, 1983, the movement of the geographical position to mean catch temperature, the latitudinal extent of SST's within one standard deviation, and the monthly low and high mean catch temperatures.

The southern California mean catch temperature of 63.7°F (17.3°C) was at about lat. 28°N in late April through May (Fig. 3); at the latitude of southern Cali-

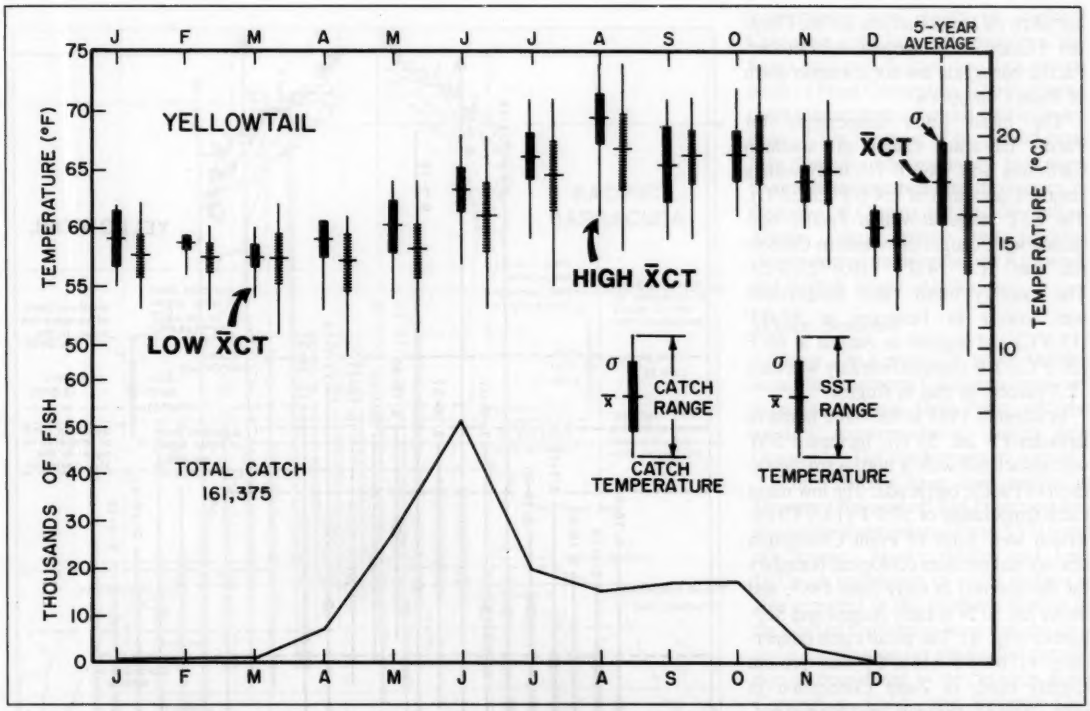

Figure 2.—Distribution of yellowtail catch off southern California and northern Mexico by month, August 1963-July 1968 for total catch, catch temperature, and SST range and means, and the standard deviations about the means (from Squire, 1982).

Table 1.—Mean catch temperatures and temperature ranges for salmon caught off northern California and for other species caught off southern California.

Species	Mean catch temperature observed: High X̄ (H X̄ct)[1] °F	(H X̄ct)[1] °C	Low X̄ (L X̄ct)[2] °F	(L X̄ct)[2] °C	Overall X̄ (X̄ct)[3] °F	(X̄ct)[3] °C	SD. °F	SD. °C	Temperature range °F	Temperature range °C
Yellowtail	70.0	21.1	57.0	13.9	63.2	17.3	3.6	2.0	51.0-74.0	10.6-23.3
Pacific barracuda	69.0	20.5	57.8	14.3	64.4	18.0	4.6	2.8	51.0-74.0	10.6-23.3
Pacific bonito	67.0	19.4	54.0	12.2	64.8	18.2	3.6	2.0	51.0-73.0	10.6-22.8
White seabass	67.0	19.4	56.8	13.8	65.2	18.4	4.5	2.4	52.5-75.0	11.4-23.8
Chub mackerel	68.0	20.0	57.0	13.9	64.0	17.8	4.0	2.2	50.0-73.5	10.0-23.0
Salmon	58.5	14.7	52.0	11.1	56.8	13.8	3.2	1.8	45.5-62.5	7.5-16.9

[1]H X̄ct = highest monthly mean temperature.
[2]L X̄ct = lowest monthly mean temperature.
[3]X̄ct = overall mean catch temperature.

fornia from late June through July; and slightly north of the latitude of Point Conception from August through mid-September. The low mean catch temperature observed for yellowtail off southern California reached latitudes north of 50°N during only one period—1-15 August during the period when a specimen was reported at Port Orford, Oreg. Sea surface temperatures cooled slightly in the northern latitudes in late August, but when they warmed again in early September the geographical position of the southern California mean catch temperature was displaced further north by late September to the approximate latitude of Monterey, Calif. (lat. 37°N). Sea surface temperatures declined in early October southward, to a point where the geographical point of the mean catch temperature was below Point Conception by early November. In 1983 yellowtail were reported off central California and SST's were high enough to extend the low mean catch temperature northward to lat. 50°N, making it reasonable to assume from temperature data that yellowtail may have migrated farther northward than recorded.

Pacific Barracuda

High catch areas in southern California are normally along the coast off San Diego, near San Clemente, and off Huntington Beach; peak catches are usually recorded in September. A few barracuda

are taken off Santa Barbara and the Channel Islands from August to October. Pacific barracuda are not common north of Point Conception.

The mean catch temperature for Pacific barracuda caught off southern California was 64.4°F (18.0°C) with a standard deviation of ±4.6°F (±2.8°C). The SST range at which Pacific barracuda were caught off southern California was 51.0°-74.0°F (10.6°-23.3°C). The monthly mean catch temperature was lowest in February at 57.0°F (13.9°C) and highest in August at 69°F (20.6°C). The catch in February was only 12.5 percent of that in August.

In summer 1983 in the more northern latitudes (> lat. 35°N), increased SST was associated with a northward movement of Pacific barracuda. The low mean catch temperature of 57.0°F (13.9°C) extended well north of Point Conception (the normal northern ecological boundary for the species) in early June 1983, and above lat. 50°N in early August and September (Fig. 4). The mean catch temperature of 64.4°F (18.0°C) was present slightly north of Point Conception in early August through mid-September, and was further north, off Monterey Bay, in late September. By early November it moved progressively southward to a point south of Point Conception. From July through mid-September temperatures favorable to Pacific barracuda were common along the California, Oregon, and Washington coasts and suitable temperatures for more northward migration appeared to be present in early August through mid-September. Catches were reported off Oregon, Washington, and as far north as Ketchikan, Alaska, (28 August, 1983) and at Uyak Bay, Kodiak Island, Alaska (August 1983).

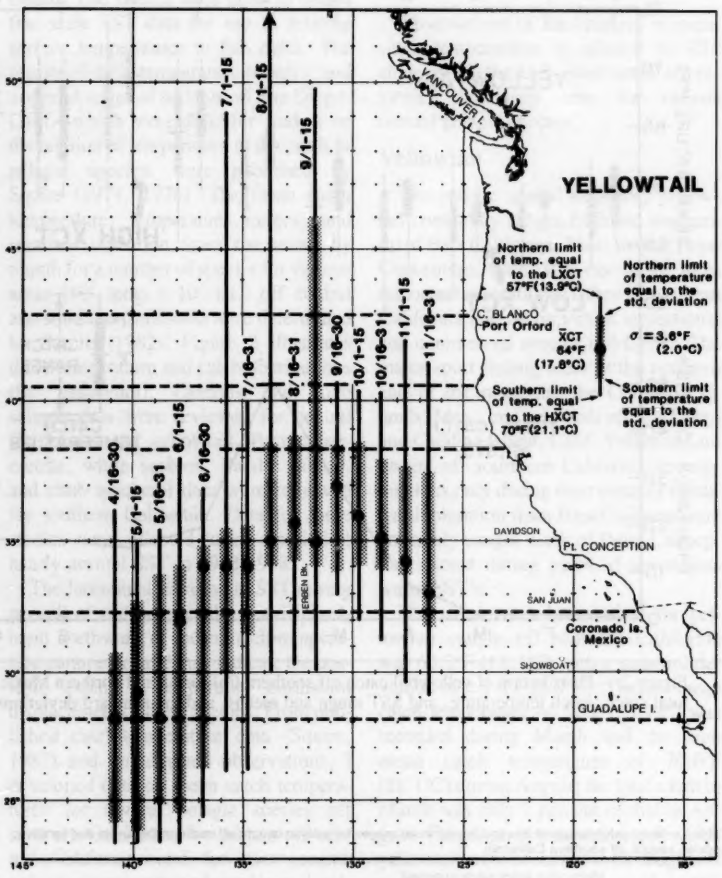

Figure 3.—Latitudinal extent semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct), shown by vertical bars, and mean catch temperature ($\bar{x}$ct; solid circles) ± one standard deviation (irregular lines above and below the means) for yellowtail caught off southern California.

Pacific Bonito

The Pacific bonito migrates considerable distances along the coast of Baja California, Mex., and into southern and central California. As with the Pacific barracuda, northern latitudinal distribution expands greatly during periods of anomalous warm-water conditions in the northeast Pacific (Radovich, 1961). Catches off southern California usually peak in August.

The distribution of the Pacific bonito is usually considered to be centered off Baja California, Mex. It was uncommon off southern California from the late 1930's until the warm year of 1957. It moved northward during the warm years of 1957-58. After declines in the population of Pacific sardine, chub mackerel, and jack mackerel, *Trachurus symmetricus*, in the early 1960's, the southern California purse seine fleet increased its fishing effort on the Pacific bonito. Apparent abundance levels decreased substantially in the late 1960's until the warm period of 1972, when northward movement of Pacific bonito from the south again resulted in an increase in apparent abundance and commercial catch off southern California (Squire, 1983). The Pacific bonito resource then decreased in the mid-1970's to lower levels of abundance and catch, as it did in the late-1960's.

Mean catch temperature for Pacific bonito off southern California was

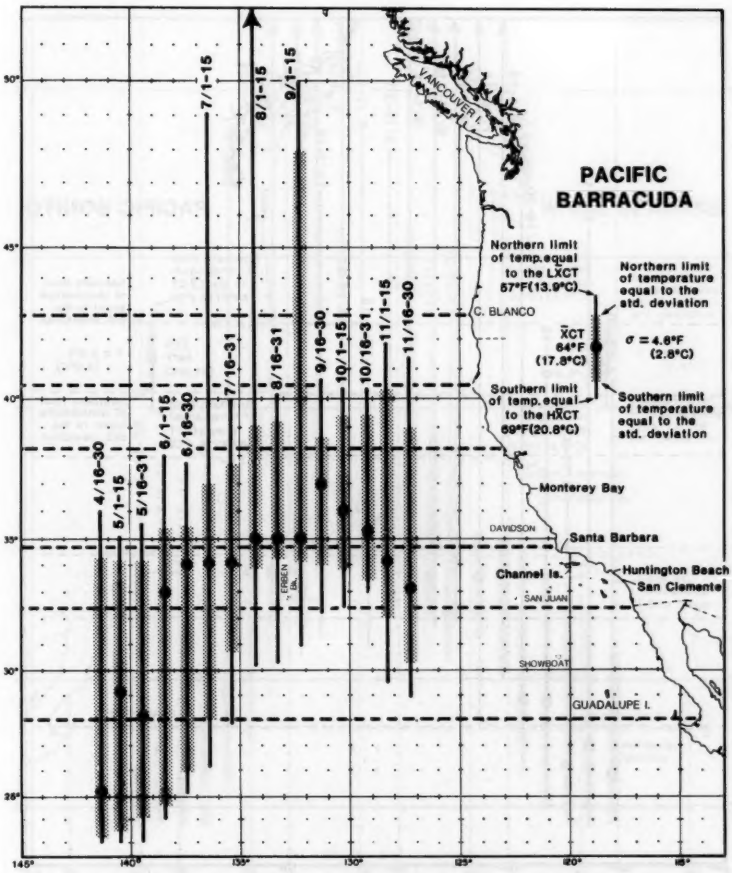

Figure 4.—Latitudinal extent by semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct, shown by vertical bars, and mean catch temperature ($\bar{x}$t; solid circles) ± one standard deviation (irregular lines above and below the means) for Pacific barracuda caught off southern California.

64.8°F (18.2°C) with a standard deviation of ±3.6°F (±2.0°C), and SST's at which Pacific bonito were caught ranged from 51.0° to 73.0°F (10.6°-22.8°C). The mean catch temperature was observed to be lowest in February at 54.0°F (12.2°C) and highest in August at 67.0°F (19.4°C); catches during February were only 5.6 percent of those during August.

Pacific bonito appear to be highly responsive to warming in the northern latitudes and are frequently caught off the coasts of northern California, Oregon, and Washington, and into the Gulf of Alaska during warm years. As shown by the geographical locations of mean catch temperatures as observed from 15 April through 30 November, 1983 (Fig. 5), the shift toward more northern latitudes of the low and mean catch temperatures observed off southern California suggests more optimum conditions for northward migration of Pacific bonito than for yellowtail or Pacific barracuda. Mean catch temperatures were south of southern California until July, off southern California until mid-August, and then moved north of Point Conception. The low mean catch temperature extended into latitudes above 52°N for most of the period from July through mid-September, indicating favorable temperatures for the species in the areas off Canada and into the Gulf of Alaska. Pacific bonito were reported caught during the summer off Kalawock and Kodiak Island, Alaska.

White Seabass

Major catch areas for white seabass along the southern California coast are from San Diego to Dana Point, with the greatest numbers being caught near Oceanside. The catch peaks in August.

White seabass have been caught in Monterey Bay and off San Francisco during warm-water years (Frey, 1971) and off Juneau, Alaska (Miller and Lea, 1972). A population of white seabass is also reported in the northern portion of the Gulf of California; however, the center of distribution for the Pacific population is considered to be between Point Conception, Calif., and Ballenas Bay, Baja California Sur, Mexico. Both recreational and commercial catches have declined substantially since the 1950's, and the recreational fishery catch off southern California declined to very low levels after the late 1950's (Young, 1969).

The mean catch temperature observed off southern California for white seabass was 65.2°F (18.4°C) with a standard deviation of ±4.5°F (±2.4°C) and ranged in southern California from 52.5° to 75.0°F (11.4°-23.8°C). The mean catch temperature was highest in August at 67.0°F (19.4°C), and lowest in April at 56.0°F (13.3°C). Catches during April were 16.6 percent of those during August.

Geographically, the mean catch temperature for southern California in 1983 was near the latitude of Cedros island in late April through May (Fig. 6), had moved northward to off southern California in early July, and reached a point north of Point Conception in late August through October. The low mean catch temperature for southern California was north of lat. 52°N from late July through mid-September. White seabass were

recorded off Westport, Wash., during mid-July 1983.

Chub Mackerel

Abundance of chub mackerel was low in the early 1960's. Beginning in 1976, a series of good year classes made this species one of the more important commercial and recreational species in southern California by 1980. Recreational fishing areas produce substantial catches of chub mackerel off San Diego, Dana Point, and Santa Monica Bay, and near Catalina Island. Catches were low during November-May, and peaked in August.

Mean catch temperature for chub mackerel off southern California was 64.0°F (17.8°C) with a standard deviation of ±4.0°F (±2.2°C), and SST's observed where Pacific mackerel were caught off southern California ranged from 50.0° to 73.5°F (10.0°-23.0°C). The monthly mean catch temperature was highest at 68.0°F (20.0°C) in August, and lowest in February at 57.0°F (13.9°C). The catch during February was 20.0 percent of that observed in August.

The mean catch temperature observed for chub mackerel off southern California shifted from the waters off Baja California, Mex., in April and May to waters off southern California by early June (Fig. 7), to a point north of the latitude of Point Conception by early August, and a point near lat. 32°N (Monterey and San Francisco) by late September. The point of mean catch temperature remained north of Point Conception until late October. The low mean catch temperature was above lat. 50°N during the period 1-15 August, 1983. Pacific mackerel were reported caught off the northern California, Oregon, and Washington coasts; into the southern part of Puget Sound, Wash.; and north to the Queen Charlotte Islands, B.C., Can., during the period June-September 1983.

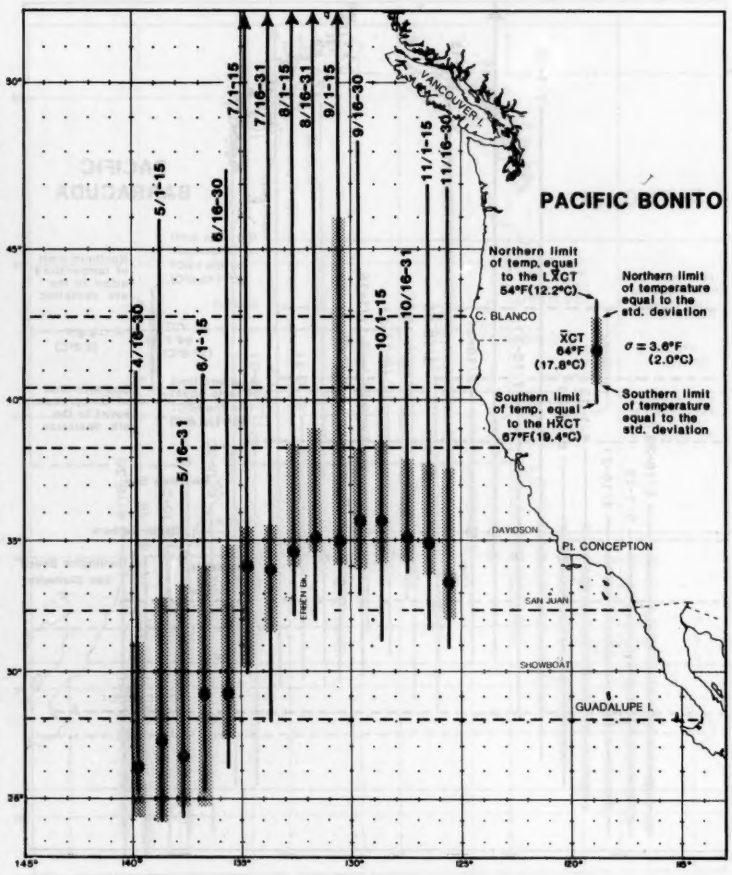

Figure 5.—Latitudinal extent by semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct, shown by vertical bars, and mean catch temperature ($\bar{x}$ct; solid circles) ± one standard deviation (irregular lines above and below the means) for Pacific bonito caught off southern California.

Yellowfin Tuna

One of the most unusual occurrences off southern California of a tropical species infrequently caught there was reflected in the large catch of yellowfin tuna in the recreational fishery in 1983. Historical catch data for recreational fishing in southern California indicated that warm periods, such as those of 1957 and 1972, produced substantial increases in catches of skipjack tuna and dolphins. However, yellowfin tuna catches increased only slightly in 1957-58 (Squire, 1983). Recreational catches recorded by Young (1969) were nil in 1953 and 1954, 1 fish in 1955, 78 in 1956, 325 in 1957 (the warm year), 13 in 1958, and 4 in 1959. During this 7-year period, the number of angler days ranged from 502,000 to 557,000, indicating that angler effort did not change markedly during the period. In April 1983, Squire (1983) forecast the possible effects of the 1982-83 warm period on southern California recreational fishing if the El Niño continued through 1983. Although the forecast (based on historical catch data) did not mention substantial increases in recreational catches of yellowfin tuna, the 1983 recreational catch of yellowfin tuna off southern California clearly set a record: More than 89,000 yellowfin tuna were reported caught by the San Diego commercial sportfishing boat fleet alone during the year (Anonymous, 1984).

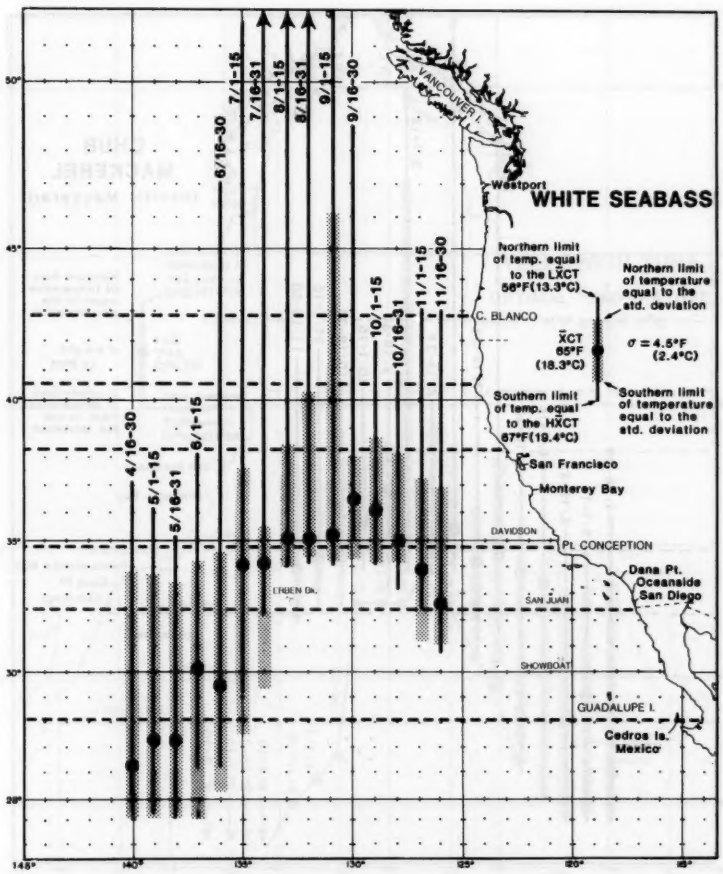

Figure 6.—Latitudinal extent by semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct, shown by vertical bars, and mean catch temperature ($\bar{x}$ct; solid circles) ± one standard deviation (irregular lines above and below the means) for white seabass caught off southern California.

Catches from the commercial sportfishing boats in other southern California ports were substantial, and catches by private boats will further increase the record 1983 total. Skipjack tuna were also caught in large numbers—San Diego landings alone totaled 73,000 fish and about 3,400 bigeye tuna, *Thunnus obesus*, were landed (Anonymous, 1984).

Inasmuch as the catches of yellowfin tuna are relatively uncommon off southern California, catch temperature data for the species in the region are not available. The most northerly area where yellowfin tuna are ordinarily taken in substantial quantities with commercial purse seines extends from west of Cabo San Lucas to south of Cedros Island, Baja Calif., Mex. The seine fishery is common in the area west of Cabo San Lucas in April, May, and June, and shifts northward to the area south of Cedros Island in August to October. Since high mean and low mean catch temperatures for this species in the area of interest are not known,

Table 2.—Monthly mean sea surface temperatures for two yellowfin tuna fishing areas off the west coast of Baja California, Mex.

Month	Mean SST's in °F and (°C)	
	West of Cabo San Lucas	South of Cedros Island
April	70°F (21.1°C)[1]	62°F (16.7°C)
May	70°F (21.1°C)	63°F (17.2°C)
June	72°F (22.2°C)	63°F (17.2°C)
July	79°F (26.1°C)	68°F (20.0°C)
August	82°F (27.8°C)	70°F (21.1°C)
September	83°F (28.3°C)	72°F (22.2°C)
October	82°F (27.8°C)	71°F (21.7°C)
November	80°F (26.7°C)	68°F (20.0°C)
December	74°F (23.3°C)	67°F (19.4°C)

[1]Underscoring indicates average temperature for the month and area having major catches of yellowfin tuna.

I must rely on the determination of average SST by examination of monthly average SST charts (Anonymous, 1969). These charts indicate the mean SST's by month for the area west of Cabo San Lucas and to the south of Cedros Island; temperatures observed are given in Table 2.

The mean temperature during periods of high catches in the area west of Cabo San Lucas was 70.7°F (21.5°C) and 71.0°F (21.7°C) south of Cedros Island. These data indicate that 71°F (21.7°C) could be considered as an optimum catch temperature. Use of this value indicates that the optimum temperatures for yellowfin tuna were located south of Cedros Island through July 1983 (Fig. 8) Sea surface temperatures increased north of Cedros Island in August, and temperatures approximating the optimum catch temperature were common off southern California in early August through October 1983. The major area of yellowfin tuna fishing by the recreational fishing fleet off southern California extended from northern Baja California, Mex., north to the latitude of Los Angeles.

Striped Marlin

Striped marlin are caught by recreational anglers with rod and reel and sometimes by commercial drift gillnets and harpoons off southern California during late summer and early fall. Striped marlin are common all year in Pacific waters off the west coast of Baja California Sur, Mex. (south of lat. 27°N). The eastern Pacific distribution was described by Miller and Lea (1972) as from Chile to Oregon.

Catch temperature studies off southern California reported by Squire (1974) indicated that the mean temperature at which striped marlin are caught off southern California is 67.8°F (19.9°C) with the standard deviation of ±0.5°F (±0.25°C). Striped marlin are caught off southern California at a temperature range of about 61°-73°F (16.1°-22.8°C). Catches appear to increase at an exponential, but highly variable, rate relative to increases in temperatures (Squire, 1985).

For the period 1 June through 30 November, 1983, the geographical locations of the mean catch temperature and the approximate normal temperature range are shown in Figure 9. Mean catch temperatures were present south of southern California in June and July. Sea surface temperatures increased off southern California in early August, and the mean catch temperature value was observed to be common to these waters from August through October. The low mean catch temperature extended northward to off San Francisco from early September to mid-October. Striped marlin were caught off the San Francisco area by drift gillnets and one was reported caught in Monterey Bay by rod and reel.

Pacific Salmon: Central California

Sea surface temperatures observed for the major recreational fishing areas for Pacific salmon from Monterey Bay to Bodega Bay, Calif., normally range from about 45° to 63°F (7.2°-17.2°C). Water temperatures in this area are low during January through May or June and lowest about April. Temperatures increase slightly from June through September, when the mean temperature peaks, and then usually begins to drop in October.

Peaks in the salmon catch for the fishing area off San Francisco (the major catch area) occur in March and July. To the north, off Bodega Bay, the catches peak in July and August. To the south, off Monterey, two catch peaks occur—one in May and one in July. Chinook salmon are most often caught, because spawning chinook salmon are in the Sacramento River system during most of the year, and these fish pass through the major ocean fishing areas off central California. The fall run of chinook salmon is the largest, and fish aggregate off the San Francisco Bay area before the spawning migration.

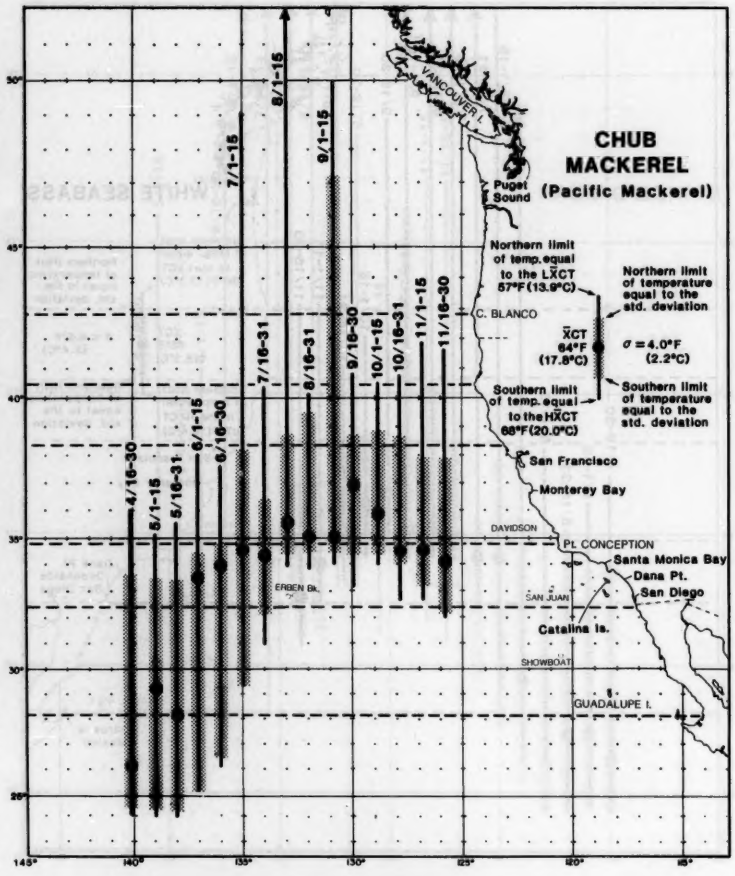

Figure 7.—Latitudinal extent by semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct, shown by vertical bars, and mean catch temperature ($\bar{x}$ct; solid circles) ± one standard deviation (irregular lines above and below the means) for chub mackerel caught off southern California.

Salmon catches off central California in 1983 followed past trends toward lower catches during abnormally warm periods. Before the 1957 warm period, the recreational catch off California (Young, 1969) had increased from about 80,000 to 90,000 fish in 1952 and 1953 to 114,000 fish in 1956. During the warm-water year of 1957, catches dropped to about 45,000 fish and remained at this lower level of 40,000-50,000 fish for several years.

About 50 percent of the salmon catch in the area from Monterey Bay to Bodega Bay is made at water temperatures of 51.8°-56.0°F (11.0°-13.3°C). The mean catch temperatures during the months of highest production ranged from 52.6° to 53.8°F (11.4°-12.1°C), off Monterey in May and June; off San Francisco the best months were June and July at 52.8°-

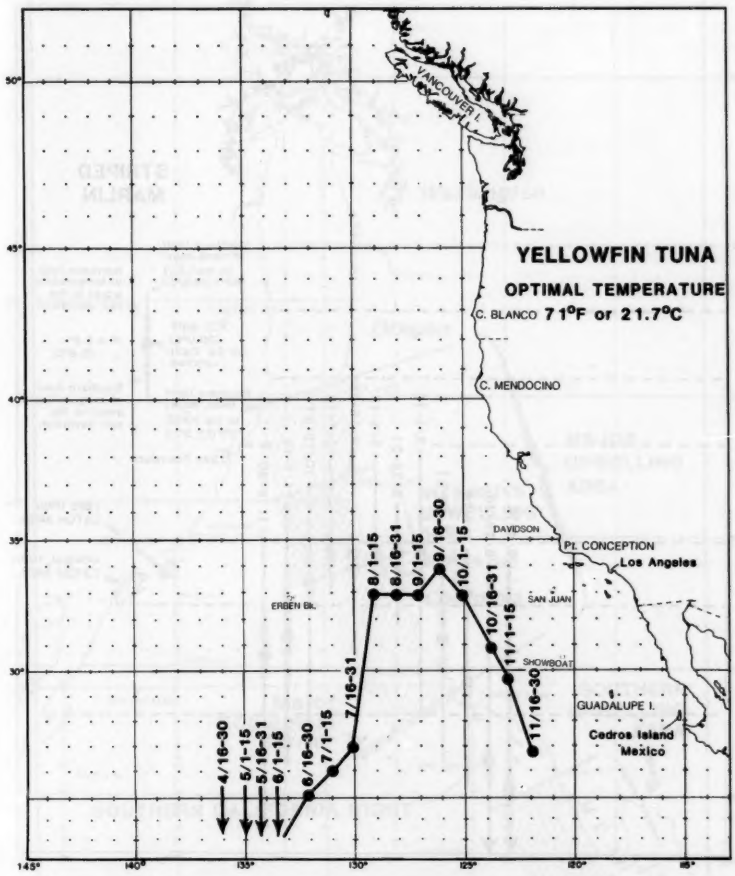

Figure 8.—The semimonthly latitudinal location of optimal catch as observed off Baja California, Mex. (71°F or 21.7°C), for yellowfin tuna during the 1983 fishing season.

54.4°F (11.6°-12.4°C), and off Bodega Bay the best catches were in July and August with a range of 51.6°-52.4°F (10.9°-11.3°C). Using temperatures of 53°F (11.7°C) for the Monterey and San Francisco areas, and 52°F (11.1°C) for off Bodega Bay as values representing optimal catch temperatures, a comparison of these temperatures with those obtained from 15-day coastal SST charts for the period 1 January through 30 October, 1983, shows that all temperature values were found to be above the optimal values observed during normally high catch periods (Table 3).

Discussion and Summary

Analysis of catch temperatures (Squire, 1982) shows that the deviation of catch about the mean catch temperature is considerable. Therefore, the mean catch temperature (high $\bar{x}$, low $\bar{x}$, or $\bar{x}$) must be viewed as it is statistically—a measure of the location of central tendency. The superficial aspects of sea surface temperature in relation to catch should be taken into consideration when one evaluates the semimonthly geographical location of the high and low mean and mean catch temperature given for yellowtail, Pacific barracuda, Pacific bonito, white seabass, and chub mackerel in Figures 3-7, and optimum catch temperatures for yellowfin tuna and striped marlin in Figures 8-9 and salmon in Table 2.

Although fishes and invertebrates are poikilothermic and function over a rather wide range of temperatures (Brett, 1956), they tend to concentrate in environments that are favorable to their metabolic requirements for successful development (Uda, 1961). Subtropical species of yellowtail, Pacific barracuda, Pacific bonito, white seabass, and chub mackerel common to southern California waters have been observed to be caught off southern California at SST's of 50.0°-75.0°F (10.0°-23.9°C), with these species showing a temperature range of from 20°F (11.1°C) to 23.5°F (13.0°C). Observations of SST's in the northeast Pacific during summer and early fall in 1983 would indicate the minimum temperatures at which some of these subtropical pelagic species caught off southern California were commonly observed in the northern portion of the Gulf of Alaska. The degree of environmental change, as exemplified by SST increases in the northern latitudes, results from physical changes in the California Current system (Reid et al., 1958), such as increases in the magnitude of the northward flowing subtropical countercurrent (the Davidson Current) and a reduction in coastal upwelling. These physical changes result in warming of the upper layers of the ocean, enabling such species as chub mackerel and white seabass to migrate to the coasts of Oregon, Washington, British Columbia, and (for some species as Pacific barracuda and Pacific bonito) even further north into the Gulf of Alaska.

The population sizes of coastal pelagic species of Pacific barracuda, white seabass, and yellowtail were considerably smaller in 1982-83 than during the warm period of 1957-58 (MacCall et al.[2]), whereas the populations of Pacific bonito and chub mackerel were only moderately reduced. Consequently the probability of

[2]MacCall, A. D., G. Stauffer, and J. P. Troadec. 1974. Stock assessments for southern California recreational and commercial marine fisheries. NMFS Southwest Fish. Cent. Admin. Rep. LJ-74-24, 144 p.

recovering Pacific bonito and chub mackerel was higher than that of recovering specimens of the other three species.

Along the coast from about Cedros Island, Baja California, to near Cape Blanco, Oreg., during the summers of normal years, a series of SST changes appear to be related to the northward coastal migration of many subtropical and tropical species (Hubbs, 1948). The southern upwelling area (Fig. 10) extends from north of Cedros Island (lat. 28°N) to about southern California (lat. 32°N). South of this area, SST's are generally higher. Increases in temperature during warm years have resulted in exponential increases in catches of striped marlin off southern California. Catches of Pacific bonito, dolphin, skipjack tuna, and yellowtail increase off southern California when upwelling is reduced in the area south of southern California.

Because the southern California Bight (area near U.S.-Mexico border to Point Conception) is characterized by a counterclockwise current flow, SST's in the northern portion (between long 119° and 120°W) are only slightly lower than those in the southern portion (Gulf of Catalina). Fish migrating into the Southern California Bight from the south encounter few environmental temperature barriers until they reach the Point Conception area (lat. 34°30'N). Point Conception is at the southern end of the major upwelling area that extends north to about Cape Blanco, Oreg. (Fig. 10), and is recognized as an ecological barrier to the northward migration of subtropical fishes (Hubbs, 1948). The upwelling

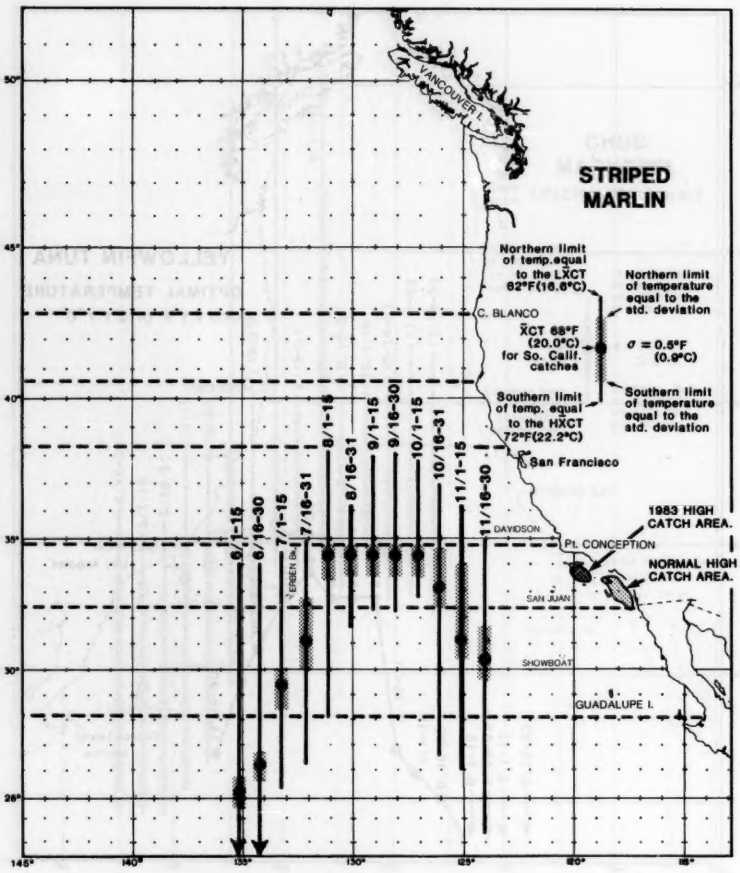

Figure 9.—Latitudinal extent by semimonthly periods in 1983 of the high mean catch temperature (H$\bar{x}$ct) and low mean catch temperature (L$\bar{x}$ct, shown by vertical bars, and mean catch temperature ($\bar{x}$ct; solid circles) ± one standard deviation (irregular lines above and below means) for striped marlin caught off southern California.

Table 3.—Upward (positive) deviation of sea surface temperatures observed in 1983 off Monterey Bay, San Francisco, and Bodega Bay in relation to optimal catch temperature values.

Locality and optimal catch temperature	January		February		March		April		May		June		July		August		September		October	
	1-15	16-31	1-15	16-29	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
Monterey Bay	6	6	5	5	3	4	4		4	2	6	6	6	6	10	9	16	10	11	10
53°F (11.7°C)	3.3	3.3	2.8	2.8	1.7	2.2	2.2		2.2	1.1	3.3	3.3	3.3	3.3	5.6	5.0	3.3	5.6	6.1	5.6
San Francisco	5	5	5	4	3	4	3		4	2	5	5	6	6	10	8	11	11	10	9
53°F (11.7°C)	2.8	2.8	2.8	2.2	1.7	2.2	1.7		2.2	1.1	2.8	2.8	3.3	3.3	5.6	4.4	6.1	6.1	5.6	5.0
Bodega Bay	5	5	5	4	4	4	4		4		5	4	5	7	10	9	9	10	11	9
52°F (11.1°C)	2.8	2.8	2.8	2.2	2.2	2.2	2.2		2.2	2.8	2.8	2.2	2.8	3.9	5.6	5.0	5.0	5.6	6.1	5.0

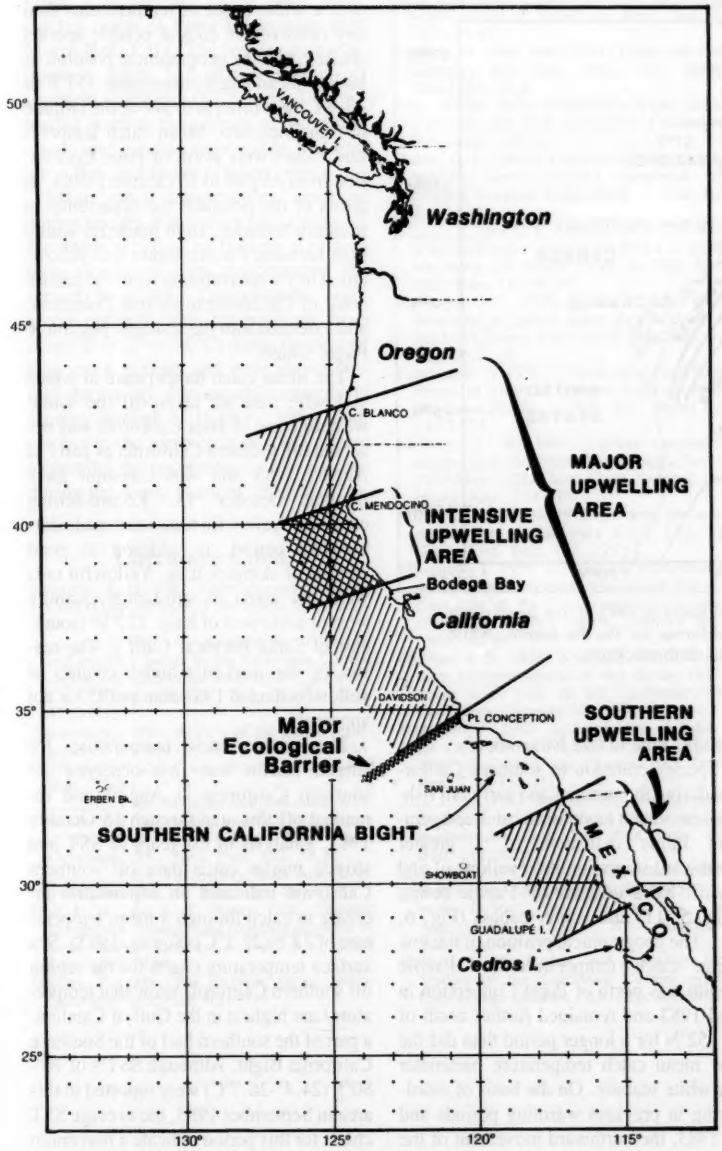

Figure 10.—Major ecological SST barrier areas to the northward migration of subtropical and tropical coastal pelagic species.

area to the north has within it areas of intensive upwelling that produce some of the lowest temperatures observed along the U.S. west coast. The area from north of Bodega Bay to Cape Mendocino, Calif., is recorded as having consistently low temperatures (Squire, 1971). Sea surface temperatures in this coastal and offshore area may provide an environment that in most years inhibits the movement of the more southern species north of San Francisco.

The eastward moving North Pacific Current, toward the coasts of central Oregon, Washington, and British Columbia and into the Gulf of Alaska (the Alaska gyre), tends to moderate coastal SST's north of lat. 45°N, which are often several degrees warmer than those found off central and northern California. Once the coastal pelagic fish common to the more southern latitudes reach a point north of the major west coast upwelling area, the isotherm structure provided by the counterclockwise Alaskan gyre may enable these fishes to move northward off the coasts of Washington and British Columbia and into the Gulf of Alaska. For example, Pacific bonito were reported in the summer of 1983 off Klawock and Kodiak Island, Alaska, and Pacific barracuda off Ketchikan, and Kodiak Island. Mean SST charts for semimonthly periods developed by the National Weather Service, National Meteorological Center, were examined for the periods in 1983 when the low mean catch temperatures for yellowtail, Pacific barracuda, white seabass, Pacific bonito, and chub mackerel were geographically above lat. 52°N (Fig. 3-7). The geographical extent of the mean low catch temperature into the Gulf of Alaska area is shown in Figure 11.

Positive SST anomalies off southern California (Fig. 1) during the warm period of 1957-1958 (McGary, 1960) peaked in September 1957 and were greater by 2°F (1.1°C) in 1957 than in 1983. Since September normally has high SST's and is a high catch-rate month off southern California for many of the subtropical pelagic species, the 1957 temperature peak came at a favorable time. In the El Niño period of 1972, positive SST anomalies peaked off southern California in October, but with less intensity of 2°-4°F (1.1°-2.2°C); however, the period was still near the time that subtropical and tropical species migrate northward. In contrast, during the warming off southern California in 1983, positive anomalies peaked first in February—not a period of northward migration of tropical and subtropical species into

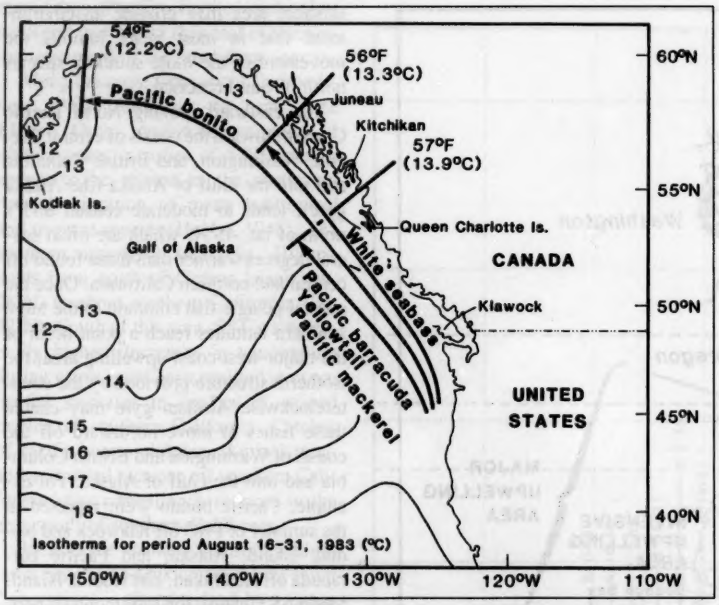

Figure 11.—Northern coastal geographical limits in 1983 of low mean catch temperature as observed off southern California for Pacific bonito, white seabass, Pacific barracuda, yellowtail, and chub mackerel.

southern California. The SST declined slightly in spring 1983 but resurged to levels of about 3°-4°F (1.7°-2.2°C) above normal from August through October, providing a sustained warm period of about 15 months during which positive anomalies of 2°F (1.1°C) or more allowed a northward extension of the distribution range for many pelagic species.

Geographical location of the temperature representing the lower limit of one standard deviation about the mean catch temperature appeared to reach its maximum northern latitudinal extent during the period 1-15 September, 1983 (see Fig. 3-7). This maximum indicated that the SST was most favorable for movement of the subtropical fishes to more northern latitudes of Oregon and Washington in early September. The geographical position of one standard deviation value below the mean was north of Point Conception for chub mackerel from July through November; yellowtail, August to October; white seabass from July through November; Pacific bonito, July through November; and Pacific barracuda, June to late November.

Species common to southern California during the summer and early fall fishing season that have mean catch temperature limits indicative of a greater northward migration than yellowtail and Pacific barracuda, are the Pacific bonito (Fig. 5, 11) and white seabass (Fig. 6, 11). The geographical position of the low mean catch temperature for Pacific bonito was north of Point Conception in mid-1983 and remained further north of lat. 52°N for a longer period than did the low mean catch temperature parameter for white seabass. On the basis of monitoring in previous warming periods and in 1983, the northward movement of the Pacific bonito appears to have exceeded that for white seabass. In 1983, the tendency for northward migration was less evident for yellowtail and white seabass than for Pacific bonito and Pacific barracuda. The mean catch temperature for yellowtail and Pacific barracuda was less frequently observed at latitudes north of Cape Blanco (lat. 43°N) and at or above lat. 52°N. Chub mackerel was caught over a wider range of temperatures than any other of the coastal pelagic species studied, and the geographical position of its low mean catch temperature (57°F or 13.9°C) was often at or above the latitude of San Francisco. Mean catch temperature values were north of Point Conception from August to 15 October, 1983. In terms of the potential for occurrence in northern latitudes, chub mackerel would rank between Pacific bonito and yellowtail. They were common from the central coast of California to British Columbia, and extended into the southern portion of Puget Sound.

The mean catch temperature at which yellowfin tuna are taken off the southwestern coast of Baja California was observed off southern California as early as August 1983 and was common there through October 15. Record-setting catches of yellowfin tuna were made during this period, in addition to good catches of skipjack tuna. Yellowfin tuna were not taken in substantial quantity west or northwest of long. 120°W (southeast of Santa Barbara, Calif.). The reason for the markedly higher catches of yellowfin tuna in 1983 than in 1957 is not apparent.

The mean catch temperature for striped marlin was first observed off southern California in August and remained off this area through 15 October 1983. Analysis of 20 years of SST and striped marlin catch data off southern California indicated an exponential increase in catch through a mean temperature of 72°F (22.2°C) (Squire, 1985). Sea surface temperature charts for the region off southern California show that temperatures are highest in the Gulf of Catalina, a part of the southern half of the Southern California Bight. Although SST's of 76°-80°F (24.4°-26.7°C) were reported in this area in September 1983, the average SST charts for this period indicate a maximum temperature of about 72°F (22.2°C). Temperatures in the normal catch areas were reported by fishermen to be considerably above the 72°F (22.2°C) maximum, and this may have resulted in a concentration of striped marlin in the northwest corner of the Southern California Bight in an area of cooler water. Excellent catches were made south of the Santa Barbara Channel Islands (near

Point Conception), along with some catches north of Point Conception near Morro Bay, Calif. The lower catch temperature limits for striped marlin off southern California (62°F or 16.7°C) extended north to the latitude of San Francisco, and catches were made in Monterey Bay and in the offshore area.

Mean catch temperatures observed during non-El Niño years for salmon off the Monterey Bay to Bodega Bay area were compared with temperatures observed in 1983. Temperatures were above optimal catch temperatures from 2° to 9°F (1.1° to 5.0°C) durng the normal high catch periods and were above normal during all semimonthly periods in January through 15 October, 1983. Poor catches in the warm year of 1983 appear to parallel the occurrence of low catches during the warm years of 1957-58.

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Atlantic Striped Bass: Stock Status and the Recreational Fishery

R. ANNE RICHARDS and DAVID G. DEUEL

Introduction

The striped bass, *Morone saxatilis*, is one of the premier sportfishes along the U.S. Atlantic coast, prized by both surf fishermen and boat anglers for its large size and fighting qualities. Its appeal has been well described by Sen. John Chafee (1980):

"Americans have 'symbols' which they rally around and which signify some part of the quality of life we all seek. The striped bass is a symbol. It is a worthy species which represents a quest, a test of endurance to fishermen, both recreational and commercial. Its sleek lines, contrasting colors of silver and black, ability to fight, and delectability have made the striper one of the most sought after fish by recreational anglers along the eastern seaboard."

ABSTRACT—The striped bass, Morone saxatilis, *has long been a prized sport fish for anglers along the U.S. Atlantic coast. Betweeen 1960 and 1970, the estimated recreational harvest of striped bass nearly doubled while the number of striped bass anglers increased by almost two thirds. However, since the mid to late 1970's, commercial and recreational harvests of striped bass have decreased to their lowest levels on record. These declines are due primarily to poor production of juveniles by the Chesapeake stock. Although stringent management measures have been implemented to rebuild the stock, juvenile production is unlikely to improve until the protected year classes mature and spawn over the next several years. The future of striped bass fishing depends on successful reproduction by these protected year classes and on management measures which maintain an adequate spawning stock.*

The striped bass has also been credited with being one of four gamefish most responsible for the popularity of surf fishing in America (McClane, 1965).

Native stocks of striped bass occur from Canada to northern Florida and in some tributaries to the Gulf of Mexico; however, the center of abundance is from Massachusetts to North Carolina (Bigelow and Schroeder, 1953). In addition, striped bass have been successfully introduced in many large freshwater lakes and reservoirs, and on the Pacific coast (Setzler et al., 1980). The striped bass is an anadromous species, and is believed to return to its natal river to spawn (ASMFC[1]). Three major stocks of striped bass occur along the Atlantic coast: The Roanoke stock, which spawns in the Roanoke River in North Carolina; the Chesapeake stock, which spawns in Maryland and Virginia tributaries of Chesapeake Bay; and the Hudson stock, which spawns in the Hudson River, N.Y. In the past, the Delaware River was an important spawning area for striped bass; however, for most of this century, production by the Delaware stock has been extremely low. Historically, the Chesapeake stock has been the major producer of striped bass along the Atlantic coast, contributing up to 90 percent of the total catch as recently as 1975 (Berggren and Lieberman, 1978).

Since the mid-1970's, commercial landings of striped bass on the Atlantic coast have declined precipitously (Fig. 1). In 1973, landings from Maine through North Carolina were at an all-time high (6,683 metric tons (t)). Just 10 years later, reported landings reached what was then an all time low (779 t), and they have continued to decrease since then. The recreational catch has experienced a similar decline. The dwindling catches in recent years are primarily a result of decreased juvenile production by the Chesapeake stock (Goodyear et al., 1985) and, to a lesser extent, by the Roanoke stock. The Hudson stock has not experienced a similar decline.

The severe decline in striped bass landings during the 1970's prompted action by state and Federal fisheries agencies, and by the U.S. Congress. In October 1981, the Atlantic States Marine Fisheries Commission (ASMFC) adopted an Interstate Fisheries Management Plan for the Striped Bass (ASMFC, 1981), which applies to the States of Maine through North Carolina. This Plan has been amended several times to incorporate increasingly restrictive management measures. In 1979, Congressional action was taken to establish the Emergency Striped Bass Research Study (ESBS), an amendment to the Anadromous Fish Conservation Act (P.L. 96-118). This law directs the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (NMFS) to monitor the status of the striped bass stocks, identify causes for the decline, and determine the economic impact of the decline. The ESBS is presently authorized to continue through 1987.

[1]ASMFC. 1987. Draft interstate fisheries management plan for the striped bass of the Atlantic coast from Maine to North Carolina. Atl. States Mar. Fish. Comm., Wash., D.C.

R. Anne Richards is with the Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543, and David G. Deuel is with the National Marine Fisheries Service, NOAA, 1825 Connecticut Avenue, N.W., Washington, DC 20235.

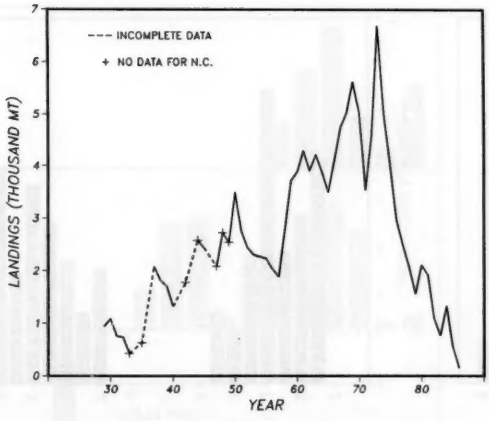

Figure 1.—Commercial landings of striped bass from Maine to North Carolina, 1929-86.

Status of the Stocks

Commercial landings statistics have been widely used as indicators of stock condition in the past (Florence, 1980; ASMFC[1]). Although landings data are influenced by many factors, the close correspondence between striped bass landings and landings per unit of gear (Koo, 1970; VanWinkle et al., 1979) suggests that trends in landings reflect actual changes in abundance of striped bass. However, since 1982, major changes in fishing regulations have restricted harvests; thus, more recent landings data are not indicative of stock abundance.

Commercial landings statistics for Atlantic striped bass are available without major gap since 1930 (Koo, 1970; Boreman and Austin, 1985; ASMFC[1]). Two features are immediately apparent upon examination of the landings data for 1930-86 (Fig. 1):

1) Landings have fluctuated widely, from lows of 497 t in 1934 (estimated by Koo, 1970) and 152 t in 1986, to a high of 6,683 t in 1973, and

2) Striped bass landings have declined steadily since the 1973 peak.

Dominant year classes occurring about every 6 years are thought to have sustained striped bass fisheries during most of this century (Merriman, 1941; Koo, 1970; Florence, 1980). This hypothesis has been supported by spectral analysis of the Maryland landings for 1930-74, which revealed periodicities of 6-8 years, and possibly 20 years (VanWinkle et al., 1979). However, the periodicities were not strongly pronounced, and the authors warned that predictions should not be made on an expectation of 6- to 8-year cycles. Indeed, landings of striped bass have declined steadily in the 12 years since this analysis, with no indication of the appearance of a dominant year class.

Chesapeake Bay Stock

The Chesapeake Bay stock of striped bass has contributed up to 90 percent of the catch in coastal areas prior to the recent decline (Berggren and Lieberman, 1978). Consequently, fluctuations in the Chesapeake stock have a major impact on landings along the entire Atlantic coast.

Sampling programs begun in 1982 have revealed a very low abundance of fish from year classes prior to 1982 in Chesapeake Bay (MDNR, 1985, 1986; Loesch and Kriete, 1984, 1985) and very few females on the spawning grounds in Maryland (MDNR, 1985, 1986). These results suggest that mortality of striped bass spawned in Chesapeake Bay during the 1970's was high enough to essentially remove them from the population by 1982. Estimates of total mortality rates for Chesapeake Bay striped bass from the 1970 year class range from 60 to 70 percent (Kohlenstein, 1980) to 93 percent (MDNR, 1985) per year for males, and 45 percent per year for females (MDNR, 1985). As a result of these high mortality rates, the female component of the striped bass stock in Chesapeake Bay is now composed primarily of year classes that are not fully mature. Restoration of Chesapeake Bay striped bass depends almost entirely upon successful reproduction by the 1982 and subsequent year classes.

The reproductive success of the Chesapeake Bay stock is measured using beach seine surveys for abundance of juvenile fish in nursery areas of the Bay. Two surveys are conducted annually, one in Maryland waters and the other in Virginia waters. The Maryland survey has been conducted since 1954 and has been used extensively to assess the status of the stocks (Schaefer, 1972; Florence 1980; Kohlenstein, 1980; Polgar, 1980; Cohen et al., 1983; Goodyear et al., 1985) and to make management decisions (ASMFC, 1981), on the assumption that the index is a valid predictor of future recruitment to the fishery. This assumption has been supported by analyses relating Maryland commercial landings to the Maryland juvenile index 2, 3, 4, and 5 years previous to the landings (Goodyear, 1985). Changes in the juvenile index accounted for 83 percent of the variation in reported commercial landings from 1964 to 1983. If the commercial landings reflect actual abundance, as the analyses of Koo (1970) and VanWinkle et al. (1979) suggest, these results indicate that the Maryland juvenile index provides a reliable measure of relative year-class strength for striped bass in Maryland waters.

The Maryland juvenile index is a pooled average of samples taken at fixed stations in the Potomac, Choptank, and Naticoke Rivers and in the Upper Bay region (Boone, 1984). The index has fluctuated widely, with a high of 30.4 striped bass per haul in 1970 and a low of 1.2 per haul in 1981 (Fig. 2). Since 1970, the juvenile index has remained low, with values lower than the 1954-70 aver-

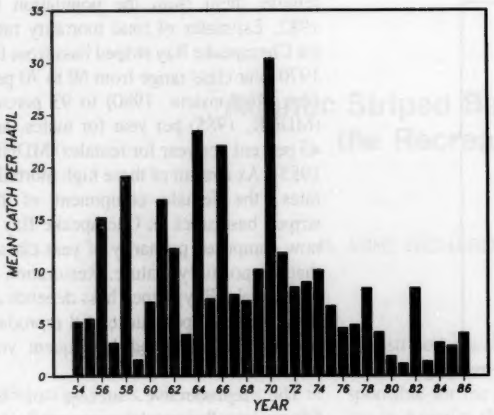

Figure 2.—Maryland juvenile index for striped bass, 1954-86.

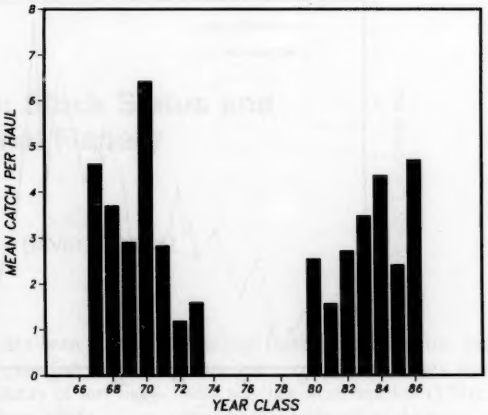

Figure 3.—Virginia juvenile index for striped bass, 1954-86. The juvenile survey was not conducted during 1974-79.

age (11.7) in 15 of the 16 years since 1970. The juvenile index for 1986 increased slightly over the 1985 value, but was only 13 percent of the maximum value in the time series.

The Virginia juvenile index is a pooled average of beach seine surveys conducted in the three major Virginia nursery areas: The James, York, and Rappahannock Rivers. The survey began in 1967, was discontinued during 1974-79, and resumed in 1980. The strong 1970 year class is evident in this series (Fig. 3), as it is in the Maryland series. The Virginia index has generally increased since 1981; however, its reliability in predicting future recruitment to the fishery is unknown.

Taken together, these surveys reveal generally poor reproductive success of the Chesapeake Bay stocks since 1970, with no indication of dominant year classes appearing. Although both indices increased in 1986, the Maryland index remains far below the long-term average. Given the virtual absence of older females on the spawning grounds, the juvenile indices have little potential to increase until significant numbers of the 1982 and subsequent year classes mature and spawn.

Hudson River Stock

In constrast to the Chesapeake Bay stock, the Hudson River stock has not experienced unusual declines in recent years. The Hudson River fishery for striped bass was closed in 1976 due to excessive levels of polychlorinated biphenyls (PCB's). Since the closure, research catches of the overwintering and spawning stocks have been composed mainly of 4- to 8-year-old fish, with ages from 2 to 16 years present (Hoff et al., In press; Kahnle and Brandt, 1985; Stang, 1986; Kahnle and Stang[2]). Estimated total mortality rates were 42 percent per year for 5- to 11-year-old fish (sexes combined) in 1985, and 30 percent per year for 6- to 12-year-old fish in 1986[3]. Although the data are not extensive, the broad age distribution and relatively low mortality rates indicate that the Hudson stock is in good condition.

Indices of juvenile abundance in the Hudson River, based on complementary beach seine and trawl surveys, also suggest that this stock is healthy. Juvenile production has remained high throughout the 1970's and 1980's (Fig. 4). The indices for the two most recent years of the seine survey have been among the lowest of the time series; however, the trawl survey index for 1986 increased while the seine index did not, suggesting a possible shift in local distribution of young striped bass to deeper water[4].

Roanoke Stock

Striped bass from the Roanoke stock appear to have a very limited migratory range (Merriman, 1941; Vladykov and Wallace, 1952; Hassler et al., 1981; Boreman and Lewis, 1987) and thus probably contribute little to fisheries along the coast. All available information on the Roanoke stock indicates that this population is severely depressed. The commercial catch of striped bass in North Carolina, sampled from January to March 1986, consisted mostly of 2-year-old fish, with very few striped bass older than 4 years of age (Winslow and Henry, 1986). The age composition of females on the Roanoke River spawning grounds reflects heavy fishing pressure: Very few females >4 years old were found on the spawning grounds in 1985 and 1986

[2]Kahnle, A. W., and D. Stang. In prep. Recent changes in survival of Hudson River striped bass. N.Y. Dep. Environ. Conserv., Hudson Riv. Fish. Unit, 21 South Putt Corners Road, New Paltz, NY 12561.

[3]D. Stang, N.Y. Dep. Environ. Conserv., Hudson Riv. Fish. Unit, 21 South Putt Corners Road, New Paltz, NY 12561. Personal commun.

[4]A. Kahnle, N.Y. Dep. Environ. Conserv., Hudson Riv. Fish. Unit, 21 South Putt Corners Road, New Paltz, NY 12561. Personal commun.

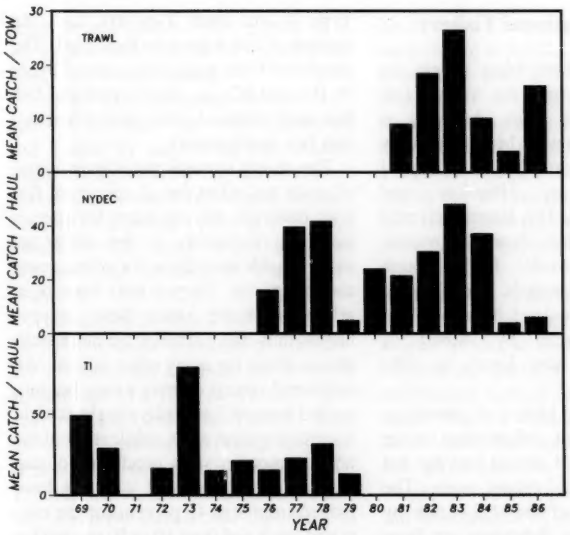

Figure 4.—Hudson River juvenile indices for striped bass. TRAWL is the trawl survey conducted by New York Department of Environmental Conservation (NYDEC) since 1981; NYDEC is the beach seine survey conducted by NYDEC since 1976; TI is a beach seine survey conducted by Texas Instruments from 1969 to 1979.

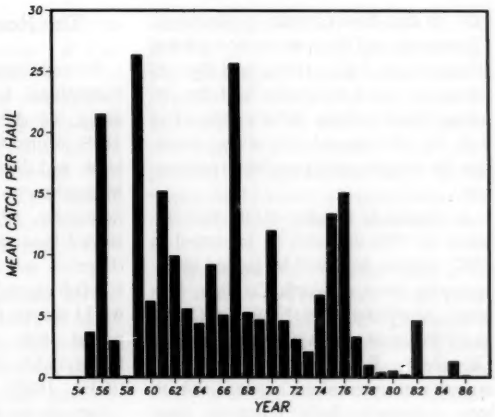

Figure 5.—Albemarle Sound juvenile index for striped bass, 1955-86.

(Winslow and Harriss, 1986; Winslow and Henry, 1986).

Indices of juvenile abundance in the Albemarle Sound nursery areas also reveal the depressed condition of the Roanoke stock. A trawl survey for juvenile striped bass in western Albemarle Sound has been conducted since 1955 (Hassler et al., 1981). The abundance of young-of-the-year striped bass has fluctuated widely over the time period; however, 8 of the 10 lowest indices have occurred in the 9 years since 1977 (Fig. 5). In 1986, the juvenile index (0.14 striped bass per tow) decreased 90 percent compared to 1985, and was only 0.5 percent of the highest index on record (26.4 in 1959). An apparent shift in nursery areas within Albemarle Sound may have caused recent abundance indices to underestimate relative year class strength[5]. However, the low abundance of mature females on the spawning grounds suggests that depressed egg deposition is probably also a factor.

Delaware River Stock

Until this century, the Delaware River system was an important producing area for striped bass. However, severe pollution in the Philadelphia area has caused oxygen depletion which apparently prevents striped bass from reaching their freshwater spawning grounds (Chittenden, 1971). Although restoration efforts are underway, striped bass production remains extremely low. A beach seine survey for juvenile finfish conducted in the Delaware River nursery areas since 1980 has captured few striped bass (Himchak and George, 1986). A slight increase in the index was seen in 1986[6], but juvenile abundance remains very low.

Current Research

Intensive efforts are presently underway to monitor the status of the stocks of Atlantic striped bass. Under the ESBS, NMFS is mandated to conduct research on striped bass population dynamics. This is done jointly with the states by supplementing on-going stock assessment programs. The overall goal is to assess recruitment, growth, and mortality in the four stocks. Information is being collected primarily through population monitoring conducted independently of fishing activities and through a coastwide tagging effort. At present, a rare opportunity exists to study striped bass stocks which are undergoing limited exploitation.

Fishery-independent monitoring of sub-adult and adult striped bass has been conducted in Chesapeake Bay by the States of Maryland and Virginia since 1982 (MDNR, 1985, 1986; Loesch and Kriete, 1984, 1985) and in the Hudson River by the State of New York since 1976 (Hoff et al., In press; Kahnle and Brandt, 1985; Kahnle and Stang, 1986; Stang, 1986). However, comparable information on the coastal stock is lacking. To provide information on this life-history stage, an additional monitoring program will begin in 1987. Striped bass will be sampled as they migrate along the eastern shore of Long Island during the

[5]H. Johnson, N.C. Div. Mar. Fish., 108 S. Water St., Elizabeth City, NC 27909. Personal commun.

[6]B. Halgren, N.J. Div. Fish, Game Wildl., Bur. Mar. Fish., Nacote Creek Lab., Star Route, Absecon, NJ 08201. Personal commun.

fall. At that time of year, a mixture of Chesapeake and Hudson stocks is present (Fabrizio and Saila, 1986), and thus information on both stocks will be obtained. Stock origins of the sampled fish will be determined to allow stock-specific estimation of population parameters.

A coastwide tagging effort was initiated in 1986 and will be expanded in 1987. Striped bass will be tagged in the spawning areas of North Carolina, Virginia, Maryland, and New York, and along the coast and in wintering areas of Chesapeake Bay. All fish are being tagged with internal anchor tags, which have relatively high retention rates (HRF, 1985) and appear to inflict minimal mortality (Dunning et al., In press). All tag returns are reported to the U.S. Fish and Wildlife Service (FWS) for distribution of rewards and entry into a master data base. At the current low levels of fishing activity, the tagged fish will be at large for a relatively long time. This will allow more complete mixing of tagged and untagged fish, and provide more extensive information on migration patterns, growth rates, and mortality than would be otbatined if fishing pressure were high.

In addition to these monitoring and tagging programs, NMFS is funding two studies which will allow estimates of stock recovery rates to be refined. These are an evaluation of mortality caused by hook and release fishing and an investigation of striped bass maturation rates. Hooking mortality is of concern because striped bass may be subject to hook-and-release fishing for 4-5 years before they reach the present harvestable size of 33 inches TL. If catch and release fishing causes significant mortality, then the advantages gained by raising minimum size limits may be reduced. Information on maturation rates is needed because ASMFC's strategy for rebuilding the Chesapeake stock is based on protecting females until they have reached spawning age. The best available information on age at maturity (Merriman, 1941) is nearly 50 years old and is inadequate for management needs. The current study will provide updated estimates of maturation rates for the Chesapeake and Hudson stocks.

The Recreational Fishery

Striped bass have been sought by recreational fishermen for many years along the Atlantic coast. As early as 1859, striped bass were being caught by hook and line from the rocks around Massachusetts Bay (Bigelow and Schroeder, 1953). The largest reported striped bass weighed about 125 pounds (Bigelow and Schroeder, 1953), though few fish exceed 70 pounds. The all-tackle world record for striped bass is a 78½-pound fish caught by Albert J. McReynolds off New Jersey in 1982 (IGFA, 1985).

Despite the long history of interest in striped bass angling, information on the recreational catch of striped bass has not been available until recent years. The earliest estimates of the U.S. catch by marine recreational fishermen are from the Saltwater Angling Surveys conducted in 1960, 1965, and 1970 (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973). These surveys were based on interviews in which fishermen were asked to report the number and average weight of each species they had caught during the previous year. Due to the lengthy recall period and other problems, these early surveys are thought to overestimate the catch (Hiett and Worrall, 1977). However, the results should be useful for examining changes in catch and effort from 1960 through 1970, because the same design was used in all three surveys.

Since 1979, an annual survey of the marine recreational fishery has been conducted by NMFS (USDOC, 1984, 1985a,b, 1986). Data are collected using two complementary methods: Interviews with fishermen at fishing sites and a telephone survey of households. The on-site interviews provide information on catch per trip, and the telephone interviews provide information on the number of trips. The catch is recorded as 1) whole fish, available for examination by interviewers (catch "Type A"), 2) fish not available in whole form (filleted, used for bait, etc., catch "Type B1"), or 3) fish released alive (catch "Type B2"). This recording method allows an important distinction to be made between harvest and catch in the recreational fishery. The estimated harvest is the sum of catch Type A and catch Type B1, i.e., the number of fish known to have died. The number of fish caught is the sum of Types A, B1, and B2, i.e., the harvest plus fish that were released alive (and whose actual fate is unknown).

The recent surveys provide estimates of catch and effort for all species of finfish; however, the estimates for species occurring frequently in the catch are more reliable than those for infrequently caught species. Striped bass have been relatively scarce since these surveys began; thus, the estimates are not as reliable as those for many other species. An additional source of error exists because striped bass are frequently caught at night in certain coastal areas, while most of the on-site interviews are conducted during the day. Coefficients of variation have ranged from 9 to 45 percent for the estimated catch and from 10 to 50 percent for the estimated harvest of striped bass on the Atlantic and Gulf of Mexico coasts.

The number of striped bass caught on the Atlantic coast increased between 1960 and 1965 and declined slightly in 1970 (Table 1). During the same period, the harvest in pounds increased steadily. This suggests that striped bass caught in 1970 were larger on average than striped bass caught in 1960 or 1965. Between 1979 and 1985, the number of striped bass caught declined 67 percent, while the estimated harvest declined 83 percent (Table 2), reflecting the decrease in striped bass abundance during this time. In 1986, the catch of striped bass doubled compared with 1985, however the harvest decreased by nearly half. These trends in catch and harvest reflect a larger number of striped bass being released alive since 1981, probably because of increased minimum size limits, recreational creel limits, and the scarcity of

Table 1.—Estimated recreational harvest of striped bass along the Atlantic coast, 1960-70. Sources: Clark (1962), Clark and Deuel (1968), Deuel (1973).

	Catch		
Year	Number (thousands)	Weight (t)	Number of anglers (thousands)
1960	9,339	17,014	487
1965	16,718	25,788	721
1970	14,237	33,246	793

larger striped bass. In 1986, 90 percent of all striped bass caught by recreational fishermen were released.

Striped bass accounted for 2.5, 3.7, and 3.1 percent of the total number of fish caught by anglers on the Atlantic coast during 1960, 1965, and 1970 respectively. In constrast, striped bass accounted for less than 1 percent of the total number of fish caught by anglers on the Atlantic coast between 1979 and 1986 (Table 2).

The number of striped bass anglers on the Atlantic coast, estimated as the number of fishermen catching one or more striped bass in a year, increased 63 percent from 1960 and 1970 (Table 1). Estimates of the number of striped bass fishermen have not been available since 1970; however, the estimated total number of marine recreational fishermen in U.S. waters increased 40 percent between 1970 and 1980 (USDOI, 1972; USDOI and USDOC, 1982). The number of striped bass fishermen is likely to have shown a parallel increase, at least through the late 1970's. Since 1979, the percentage of fishermen identifying striped bass as the primary species sought has decreased steadily (Table 3). In 1979, the striped bass ranked third among the 15 primary species sought in the Mid-Atlantic region, but it dropped to tenth by 1985 and below fifteenth in 1986 (Table 3).

Conversion of the recreational harvest from numbers to weight allows the recreational harvest to be compared with the commercial landings. Estimates of the recreational harvest in weight were obtained directly through personal interviews with fishermen in the 1960, 1965, and 1970 surveys. For 1979-86, the weight of recreationally harvested fish can be estimated by assuming that catch Type B1 fish have the same average weight as catch Type A fish. For 1960, 1965, and 1970, respectively, the estimated recreational harvest was 4.4, 7.4, and 6.6 times the commercial harvest. The recreational harvest approximately equalled the commercial landings averaged over 1979-86; although the relationship varied between years. These comparisons are approximate only, as the recreational harvest is overestimated for the 1960s and probably underestimated for 1979-86.

Most striped bass angling occurs in inland waters, however there is considerable variation in the percentage caught in the ocean versus in inland areas (Table 4). A relatively large proportion of the catch in ocean waters occurs within 3 miles of shore. In nearly all years, the catch by boats has exceeded the catch from shore, averaging 67 percent of the total catch from 1979 through 1985 (Table 5). Most boat fishing is from private or rental boats. The catch from party/charter boats averaged only 9 percent of the total catch from 1979 to 1985, and only 2 percent since 1983.

Management Regulations

The striped bass fishery has a long history of management. The earliest regulation on striped bass, restricting netting in the Hudson River, was enacted in 1892 in New York. The first minimum size limits were instituted in 1912 (Virginia, 10 inches) and 1913 (New Jersey, 12 inches) (ASMFC[1]). In response to a decline in landings during the mid-1930s, the ASMFC recommended that a coastwide 16-inch minimum size limit be instituted (Neville, 1942). This recommendation resulted in adoption of additional regulations during the 1940's by most of the coastal states (see ASMFC[1] for a detailed review).

Between the late 1940's and the late 1970's, few additional regulations were imposed on striped bass fishing. However, in 1979, the ASMFC began preparing an Interstate Fisheries Management Plan for the Striped Bass (ASMFC, 1981) in response to the severe decline in landings in the mid-1970s. When the Plan was adopted in 1981, it called for a minimum size limit of 14 inches TL in the producing areas (Albemarle Sound, Chesapeake Bay and Delaware Bay, and the Hudson River) and 24 inches TL along the coast. However, hook and line

Table 2.—Estimated number of striped bass caught and harvested (in thousands) along the U.S. Atlantic coast, 1979-86. Sources: USDOC (1984, 1985a, b, 1986).

Year	Catch (thousands)	Harvest (thousands)	Percent released alive	Wt. of harvest (t)	Striped bass as % of total recreational harvest
1979	2,014	1,324	34	2,975	0.73
1980	562	417	26	798	0.20
1981	893	798	11	617	0.45
1982	910	243	73	1,584	0.42
1983	572	290	49	1,182	0.22
1984	627	128	80	451	0.25
1985	665	225	66	797	0.28
1986[1]	1,401	141	90	852	0.50

[1]Source: Unpubl. NMFS data.

Table 3.—Percent of recreational fishermen identifying striped bass as the primary species sought, and rank of striped bass among the top 15 species sought in the Mid-Atlantic and North-Atlantic regions, 1979-86. Sources: USDOC (1984, 1985a,b, 1986).

Year	Percent seeking striped bass		Rank of striped bass	
	N. Atl.	Mid-Atl.	N. Atl.	Mid-Atl.
1979	4.0	9.6	6	3
1980	3.9	4.5	4	5
1981	3.6	3.0	5	5
1982	3.1	1.5	7	6
1983	3.2	2.6	7	6
1984	2.8	2.9	6	6
1985	2.6	0.9	7	10
1986[1]	2.1	N.A.[2]	8	>15

[1]Source: Unpubl. NMFS data.
[2]Data not available.

Table 4.—Estimated recreational catch of striped bass on the Atlantic coast by area fished, 1979-86. Numbers may not add to total due to rounding. Sources: USDOC (1984, 1985a,b, 1986).

Year	Catch (thousands of fish)				
	Ocean <3 mi.	Ocean >3 mi.	Inland	Undefined	Total
1979	331	88	1,232	364	2,014
1980	14	3	496	48	562
1981	79	12	794	8	893
1982	114	69	723	4	910
1983	286	37	206	44	572
1984	363	1	262	1	627
1985	163	0	500	2	665
1986[1]	820	15	566	—[2]	1,401

[1]Source: Unpubl. NMFS data.
[2]Less than 1,000 fish.

Table 5.—Estimated recreational catch of striped bass on the Atlantic coast by mode of fishing, 1979-86. Sources: USDOC (1984, 1985a,b, 1986).

Year	Catch (thousands of fish)			
	From shore	From Party/ charter boats	From Private/ rental boats	Total
1979	128	365	1,520	2,014
1980	84	61	417	562
1981	456	28	409	893
1982	597	56	258	910
1983	282	4	286	572
1984	303	5	319	627
1985	193	29	444	665
1986[1]	614	66	721	1,401

[1]Source: Unpubl. NMFS data.

fishermen could retain four fish per day and net fishermen up to 5 percent of their daily catch between the old and new size limits. State-established maximum size limits were retained, and spawning areas were closed to fishing during the spawning season (ASMFC, 1981). The Plan was subsequently amended several times to incorporate increasingly restrictive management measures. The most recent amendment to the Plan was instituted to ". . . prevent directed fishing mortality on at least 95 percent of the 1982 year class females, and females of all subsequent year classes of Chesapeake Bay stocks until 95 percent of the females of these year classes have an opportunity to reproduce at least once." This objective is being met primarily by increasing the minimum size limits to stay ahead of the growth of the 1982 year class. By the summer of 1988, a minimum size limit of 33 inches TL will be required in all areas where striped bass fishing is allowed.

In addition to increased size limits, some states have imposed creel limits, closed seasons, or total closures. Other restrictions have been instituted because of potential health hazards. New York closed the Hudson River fishery in 1976 and the Long Island fishery in 1986 because of PCB contamination. In Rhode Island, sale of striped bass has been prohibited since 1986 for the same reason; however, recreational fishing is allowed with a one fish per day creel limit. Regulations in place as of 31 December 1986 that affect the recreational fishery are summarized in Table 6.

Table 6.—State regulations in place as of 31 December 1986 that affect fishing for striped bass (ASMFC, text footnote 1).

State	Min. size limit (TL)	Daily creel limit	Season	Other
ME	33"	2	No closed season	Hook & line only, no sale.
NH	33"	2	No closed season	Hook & line only.
MA	33"	[1]1	No closed season	Hook & line only, sale permitted.
RI	33"	1	No closed season	No sale due to PCB contamination.
CT				Legislated closure, no possession.
NY				Closure due to PCB contamination.
NJ	24"	5	No closed season	Hook & line only, no sale.
PA	31"	2	No closed season	Hook & line only.
DE				Moratorium, no possession.
MD				Moratorium, no possession.
PRFC[2]	24"	5	Closed 1 Dec. to 31 May	34-inch maximum size limit.
DC	24"	2	Closed 1 Dec. to 31 May	Hook & line only, no sale.
VA	24" (B[3]) 30" (O)	5 2 over 40"	Closed 1 Dec. to 31 May	
NC	14"	3	No closed season	Albemarle Sd.
	16"	3	No closed season	Roanoke R.; inland. Atlantic ocean closed.

[1]Catch and possession.
[2]Potomac River Fisheries Commission.
[3]B = bay, O = ocean.

Future Conditions

Ultimately, the quality of recreational fishing for striped bass will depend on reestablishing conditions which foster successful reproduction and subsequent recruitment to the harvestable stocks. Achieving these goals will depend both on increasing the size of the spawning stocks and on the occurrence of environmental and water quality conditions conducive to survival of larvae and juveniles.

In the immediate future, an increase in the number of striped bass is to be expected as a result of management measures which have substantially protected the 1982 and subsequent year classes from exploitation. By the time members of the 1982 year class reach the minimum size limit of 33 inches TL, they will have been afforded 3-4 years of additional protection compared with year classes that became vulnerable at 12 or 14 inches. As a result, the 1982 year class may actually exceed the abundance of the 1970 year class at these ages (USDOI and USDOC, 1986). In addition, harvesting striped bass at 33 inches TL will maximize the yield from each individual entering the population (Goodyear, 1984). Thus, short term increases in the harvest of striped bass can be expected due to increases in abundance and increased size of the available fish. However, unless these protected year classes are able to reproduce successfully, their contribution to the fishery will be short-lived.

Long-term prospects for striped bass fisheries depend on sustained successful reproduction and subsequent recruitment to the fishable stocks. These in turn hinge critically on the levels of fishing mortality which the stocks are subjected to, and on water quality and environmental conditions in the spawning and nursery areas. All female striped bass in a year class are not mature until the age of 6 years (Merriman, 1941), thus there must be significant escapement of females from fishing to allow them to spawn even once. The scarcity of mature females on the spawning grounds in Maryland since 1982 suggests that fishing mortality during the 1970's was excessive. At the annual fishing mortality rates estimated for Chesapeake Bay females in the 1970's, egg production of female recruits would be decreased by 97 pecent to more than 99 percent compared with an unfished stock (based on Goodyear, 1980).

Adequate egg production clearly does not guarantee adequate recruitment. Survival of eggs and larvae of most highly fecund fish species is extremely variable and results in variable recruitment to fisheries (Sissenwine et al., In press). Much of this variability is thought to be caused by naturally occurring, random fluctuations in environmental conditions. However, the larvae of fish which spawn where human activities contaminate the water must run a further gauntlet. Studies conducted in four Maryland spawning areas since 1984 have shown that river water can be toxic to striped bass larvae and juveniles (Hall, 1984, 1985; Hall et al., 1986; CNFRL[7]). Thus, both natural conditions and contaminant levels must be favorable to permit survival. Although natural environmental variability cannot be controlled, removal of contaminant stress would increase the probability of

[7]CNFRL. 1984, 1986. Impact of contaminants on striped bass in the Chesapeake Bay - a summary of research on pH/contaminant interactions in laboratory and field investigations. U.S. Fish Wildl. Serv., Col. Natl. Fish. Res. Lab., Columbia, Mo. prog. reps., var. pagin.

young striped bass encountering favorable environmental conditions. Further, the probability of young striped bass being present during favorable water quality conditions would be increased by building a spawning stock comprised of several age classes. Young female striped bass spawn later than older ones (Hollis, 1967); thus, the length of the spawning season would be extended by maintaining several age classes in the spawning stock.

Evidence from historical records suggests that striped bass population levels have always fluctuated widely, due most likely to the influence of dominant year classes. Despite the variable nature of production of striped bass, the quality of fishing could be maintained at a more consistent level if fishing mortality were lower than in the recent past. Lower mortality would extend the harvest of a dominant year class over a larger number of years, thus reducing fluctuations in harvest.

In the past, management of striped bass has been based primarily on minimum size limits. Although size limits restrict the harvest of undersized fish, they allow unrestricted harvest of "legal" fish. Thus, excessive harvest of fish can occur despite size limits, potentially resulting in reduced spawning stock size and subsequent recruitment failure. To avoid these problems, fishing mortality must be controlled through additional management measures such as creel limits and seasonal and area closures.

Recent regulations have focused on reducing fishing mortality and increasing the number of spawning females. If and when the stock is restored, these regulations will be relaxed. However, future management will need to be more restrictive than in the past to avoid repeating the experience of the 1970s.

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Abundance of Spanish Mackerel, *Scomberomorus maculatus*, in the Southeastern United States Based on Charterboat CPUE Data, 1982-85

BARBARA JAYNE PALKO, LEE TRENT, and HAROLD A. BRUSHER

Introduction

The Spanish mackerel, *Scomberomorus maculatus*, a member of the family Scombridae, is closely related to the king mackerel, *S. cavalla*, the cero, *S. regalis*, and the recently-described Brazilian Spanish mackerel, *S. brasiliensis* (Collette and Russo, 1984). All except *S. brasiliensis* are widely distributed throughout the western U.S. Atlantic with centers of abundance in Florida. The Spanish mackerel supports important commercial and recreational fisheries in the U.S. south Atlantic and Gulf of Mexico (Trent and Anthony, 1979). It is prized as a food item and as a highly desirable recreational fish. The direct economic value of the Spanish mackerel resource is considerable. In 1985, about 4.3 million pounds were landed by commercial fishermen in the United States, and it was estimated that about 2.5 million pounds were landed by recreational fishermen in the mid-Atlantic, south Atlantic, and Gulf of Mexico (Nichols, 1986).

The Spanish mackerel fisheries of the southeast United States are presently being regulated under a joint fishery management plan (FMP) developed by the Gulf of Mexico and South Atlantic Fishery Management Councils (1983, 1985). Basic to the formulation and use of the mackerel FMP are various commercial and recreational fisheries statistics that include estimates of total effort, total catch, and catch per unit effort (CPUE). Detailed CPUE data for Spanish mackerel over broad geographic areas have become available only recently. In 1982, a survey was initiated to obtain daily catch and effort data on fishes commonly caught by charterboats in the southeast United States (Brusher et al., 1984). This survey was continued through 1985 and generated valuable CPUE data on Spanish mackerel. This paper compares the data among fishing methods, fishing zones, areas, seasons, and years with historical data generated by other surveys.

The authors are with the Panama City Laboratory Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407.

ABSTRACT—Catch per unit effort (CPUE) data for Spanish mackerel, Scomberomorus maculatus, *over a broad geographic area were obtained from charterboats. In 1982, a survey was initiated to obtain daily catch and effort data on fishes commonly caught by charterboats in the southeast United States. Boat effort and Spanish mackerel CPUE data obtained from this survey during 1982-85 were analyzed. The offshore fishing zone (>10 fathoms) received the highest amount of trolling and "other fishing" efforts; the nearshore fishing zone (≤10 fathoms) received the second highest trolling effort and lowest "other fishing" effort; the estuarine fishing zone received the lowest trolling effort and the second lowest "other fishing" effort. CPUE of Spanish mackerel by "other fishing" was much lower than trolling for most areas and years. CPUE was highest in the estuarine zone when compared with the nearshore and offshore zones. In the southeastern United States from North Carolina to Texas, the highest CPUE occurred in areas within the eastern Gulf of Mexico from Louisiana to southwest Florida each year. Seasonally CPUE of Spanish mackerel was high in the warmer months in Georgia, the Carolinas, and the northern Gulf of Mexico states and in the colder months in the southeastern areas of Florida. Significant differences in CPUE among years were detected only in North Carolina and Louisiana.*

Methods of Obtaining Data

Recreational fishing data were obtained through contract with charterboat captains (Brusher et al., 1984). Data were obtained from 9 charterboats in 5 areas in 1982 (Williams, Brusher, and Trent, 1984; Brusher et al., 1984), from 100 boats in 16 areas in 1983 (Williams et al., 1984; Brusher and Palko, 1985), from 31 boats in 9 areas in 1984 (Williams et al., 1985), and from 43 boats in 16 areas in 1985 (Brusher and Palko, 1986). In 1983, the year of highest coverage, the number of selected captains per area represented about 10 percent of the total number of charterboats fishing in 16 areas (Fig. 1). Data were not reported for the U.S. Caribbean (area 16) because Spanish mackerel do not occur there.

Logbooks containing weekly log forms were provided to the captains, who completed the forms using the following definitions.

1) Fishing zone. Three fishing zones, estuarine, nearshore, and offshore, were identified as defined in Table 1. These and combinations of these zones resulted in the 7 categories for analysis.

2) Fishing method. "Trolling" was defined as fishing with hooks and line at

Table 1.—Fishing zones (1, 2, and 3) and combinations of fishing zones used to record and analyze catch and effort data.

Code	Zone(s)	Definition
1	Estuarine	Bays and sounds
2	Nearshore	0-10 fathoms in ocean or Gulf
3	Offshore	Beyond 10 fathoms in ocean or Gulf
4	Estuarine & nearshore	Combination of 1 & 2
5	Estuarine & offshore	Combination of 1 & 3
6	Nearshore & offshore	Combination of 2 & 3
7	Estuarine, nearshore, & offshore	Combination of 1, 2, & 3

any depth while the boat was moving under its own power. "Other fishing" included all other fishing methods, such as bottom fishing, drift fishing, and flylining.

3) Hours actually fished. This was the total number of hours fished by a single boat on all of its trips for one day using a particular method. Only actual fishing times, rounded to the nearest half-hour, were reported. Running times when hooks were not in the water were specifically excluded.

4) Number caught. The number of each species caught (including releases) was recorded.

Methods of Analyzing Data

Effort was reported in two units, a boat-fishing-day and a boat-fishing-hour. A boat-fishing-day was defined as all fishing that occurred (trolling, other fishing, or both) from a single boat in a single day. Trips were combined if more than 1 trip occurred in a single day. A boat-fishing-day was recorded for each method of fishing on days that both types of fishing occurred. A boat-fishing-hour was defined as the fishing that occurred on one boat in a single hour by a single method of fishing.

Our CPUE estimator was defined as "the number of Spanish mackerel caught per boat-fishing-hour" and was computed for each boat-fishing-day for each method of fishing. The following notations were used in the computations:

$$CPUE = X_i = \frac{No.\ of\ mackerel\ caught}{Hours\ of\ fishing}$$

$$\bar{X} = Mean\ CPUE = \frac{\sum_i X_i}{n_i}$$

$$s^2 = \frac{\sum_i X^2{}_i - \left(\sum_i X_i\right)^2 \Big/ n}{n-1}$$

where

n = Number of boat fishing days and

$s_{\bar{X}}$ = Standard error of the mean

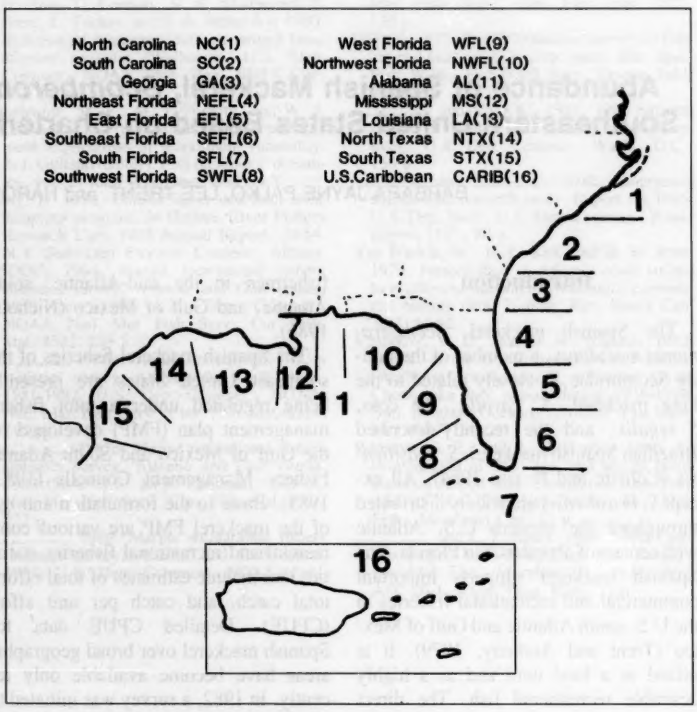

Figure 1.—Geographic areas of the charterboat survey.

$$= \sqrt{\frac{s^2}{n}} = \frac{s}{\sqrt{n}}$$

$CI_{(95\%)}$ = 95% confidence interval

$$= \bar{X} \pm t_{.05} s_{\bar{X}}$$

$$Log\ CPUE = Log_{10}\ (X_i + 1)$$

CPUE and Log CPUE were analyzed graphically (means, ranges, and standard deviations) and Log CPUE was compared among zones, areas, and years using a one-way analysis of variance with unequal replication and Duncan's multiple range test (Steel and Torrie, 1960).

CPUE data were compared among years for those areas and zones (1, 2, 3, and 1-7) where sufficient data were available. Sufficient is defined as: 1) Having at least 4 monthly means within each year and at least 3 years of data for a particular area and zone, 2) having exluded months in which all values were zero, and 3) having at least one annual mean (arithmetic) greater than 0.1 within the set to be compared. The monthly mean of log (CPUE + 1) was used as the observation. Arithmetic means are reported even when the statistical comparisons were made on the log values.

Distribution of Fishing Effort Among Habitats and Months

Fishing effort among zones 1-3 (Table 1) was evaluated to determine where most of the charterboat fishing effort occurred by each method of fishing (Table 2). The offshore zone (zone 3) with water depths >10 fm received the highest amount of effort; each year over 48 percent of the effort (trolling or other fishing), in addition to the contributions from

Table 2.—Number of boat fishing days expended by fishing zone, method of fishing, and year.

Year and method of fishing	Variable	Fishing zone 1	2	3	4	5	6	7	Total
1982 Trolling	No. of boat days	15	204	499	22		70		810
	Percent of total	1.8	25.2	61.6	2.7		8.6		
Other	No. of boat days	16	9	199			2		226
	Percent of total	7.1	4.0	88.1			0.9		
	Subtotal	31	213	698	22		72		1,036
	Percent	3.0	20.6	67.4	2.1		6.9		
1983 Trolling	No. of boat days	207	1,367	3,864	66	5	864	3	6,376
	Percent of total	3.2	21.4	60.6	1.0	0.0	13.6	0.0	
Other	No. of boat days	790	701	1,781	87	4	321	1	3,685
	Percent of total	21.4	19.0	48.3	2.4	0.1	8.7	0.0	
	Subtotal	997	2,068	5,645	153	9	1,185	4	10,061
	Percent	9.9	20.6	56.1	1.5	0.0	11.8	0.0	
1984 Trolling	No. of boat days	25	639	1,751	8	1	440	1	2,865
	Percent of total	0.9	22.3	61.1	0.3	0.0	15.4	0.0	
Other	No. of boat days	274	248	1,231	22	1	35		1,811
	Percent of total	15.1	13.7	68.0	1.2	0.1	1.9		
	Subtotal	299	887	2,982	30	2	475	1	4,676
	Percent	6.4	19.0	63.8	1.7	0.0	10.2	0.0	
1985 Trolling	No. of boat days	55	901	2,104	14	77	415		3,566
	Percent of total	1.5	25.3	59.0	0.4	2.2	11.6		
Other	No. of boat days	324	514	1,206	19	3	72		2,138
	Percent of total	15.2	24.0	56.4	0.9	0.1	3.4		
	Total	379	1,415	3,310	33	80	487		5,704
	Percent	6.6	24.8	58.0	0.6	1.4	8.5		
1982-85 Trolling	No. of boat days	302	3,111	8,218	110	83	1,789	4	13,617
	Percent of total	2.2	22.8	60.4	0.8	0.6	13.1	0.0	
Other	No. of boat days	1,404	1,472	4,417	128	8	430	1	7,860
	Percent of total	17.9	18.7	56.2	1.6	0.1	5.5	0.0	
	Total	1,706	4,583	12,635	238	91	2,219	5	21,477
	Percent	7.9	21.3	58.8	1.1	0.4	10.3	0.0	

Table 3.—Numbers of hours and days spent fishing by charterboats by month, area, type of fishing, and year (H=hours and D=days).

Area and type of fishing	Year	Jan. H	Jan. D	Feb. H	Feb. D	Mar. H	Mar. D	Apr. H	Apr. D	May H	May D	June H	June D	July H	July D	Aug. H	Aug. D	Sept. H	Sept. D	Oct. H	Oct. D	Nov. H	Nov. D	Dec. H	Dec. D	Total H	Total D
NC	1982							112.0	22	261.0	40	314.0	43	358.5	51	120.0	20	120.0	20	82.5	13					1368.0	209
Troll	1983							98.0	25	508.5	89	732.0	124	782.0	134	923.0	151	689.0	114	647.0	108	111.0	20	8.0	2	4498.5	767
	1984							53.0	13	158.5	30	287.5	56	309.5	52	327.0	58	214.0	37	289.5	51	138.5	28	0.0	0	1777.5	325
	1985							33.5	7	225.0	42	257.0	46	359.5	60	305.0	49	237.0	40	131.5	29	84.0	18	5.0	2	1637.5	293
Other	1982							0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0					0.0	0
	1983							53.0	10	50.0	10	60.0	12	70.0	15	62.0	14	49.0	10	6.0	2	25.0	4	0.0	0	375.0	77
	1984							6.0	2	5.0	1	21.5	4	24.0	5	20.0	4	8.0	3	6.0	1	0.0	0	6.0	1	96.5	21
	1985							0.0	0	0.0	0	24.5	9	27.5	10	10.5	3	13.0	3	0.0	0	8.0	4	1.0	1	84.5	30
SC	1982																										
Troll	1983							18.5	4	115.5	23	119.0	23	138.5	25	194.0	30	104.0	18	96.0	17	46.0	8			831.5	148
	1984																										
	1985							16.0	3	32.0	5	92.0	20	126.0	29	132.0	24	65.0	14	64.5	19	30.0	8			557.5	122
Other	1982																										
	1983							67.0	8	64.0	14	48.0	12	43.0	9	78.0	16	120.0	13	0.0	0	0.0	0			420.0	72
	1984																										
	1985							0.0	0	0.0	0	18.0	6	7.0	3	3.0	1	6.0	2	6.0	3	0.0	0			40.0	15
GA	1982																										
Troll	1983							0.0	0	25.0	6	36.5	9	37.5	8	74.0	14	7.5	2	0.0	0	0.0	0			180.5	39
	1984																										
	1985					0.0	0	11.5	5	28.0	10	59.0	14	70.0	15	20.0	5	0.0	0	0.0	0	0.0	0			188.5	49
Other	1982																										
	1983							30.0	3	39.0	8	22.5	7	21.0	5	3.0	1	1.5	1	0.0	0	0.0	0			117.0	25
	1984																										
	1985					17.5	4	35.5	7	91.5	20	75.0	20	69.0	16	22.0	5	0.0	0	0.0	0	0.0	0			310.5	72
NEF	1982																										
Troll	1983							43.5	11	112.5	21	87.5	16	76.0	14	103.5	18	32.0	6	57.0	14	21.0	6	7.0	1	540.0	107
	1984																										
	1985					0.0	0	53.0	11	146.0	29	109.5	20	87.5	18	75.5	19	27.0	7	25.5	10	9.0	3	3.0	1	536.0	118
Other	1982																										
	1983							82.0	14	15.5	5	53.0	10	16.0	5	29.0	6	13.5	3	21.5	5	72.0	17	0.0	0	302.5	65
	1984																										
	1985					4.0	1	57.0	14	12.5	3	50.5	12	36.0	10	33.5	10	25.5	8	30.0	9	42.0	12	43.0	12	334.0	91
EF	1982																										
Troll	1983					106.5	21	323.5	86	348.0	89	369.0	97	459.0	116	494.0	120	300.0	73	226.5	63	244.0	63	202.5	43	3073.0	771
	1984	263.5	46	250.0	44	243.0	41	330.5	71	169.5	49	180.0	50	194.0	47	221.0	49	95.0	24	96.5	30	95.5	26	129.5	26	2268.0	503
	1985	183.0	30	203.0	39	273.0	49	124.0	33	159.0	44	148.5	43	172.0	54	130.0	33	56.0	15	71.5	22	80.5	25	30.0	11	1630.5	398

Continued on next page.

Table 3.—Continued.

Area and type of fishing	Year	Jan. H	Jan. D	Feb. H	Feb. D	Mar. H	Mar. D	Apr. H	Apr. D	May H	May D	June H	June D	July H	July D	Aug. H	Aug. D	Sept. H	Sept. D	Oct. H	Oct. D	Nov. H	Nov. D	Dec. H	Dec. D	Total H	Total D
Other	1982																										
	1983					8.0	2	85.5	36	65.5	34	85.5	40	76.5	30	50.0	23	55.5	15	27.5	11	14.5	11	3.0	4	471.5	206
	1984	1.5	3	24.5	12	28.5	15	47.0	26	56.0	20	49.0	19	30.0	14	27.5	18	22.5	12	36.5	11	26.0	10	27.0	8	376.0	168
	1985	18.0	6	36.0	12	65.5	16	18.5	11	51.0	26	45.5	25	85.0	35	27.0	12	36.5	10	69.0	17	50.0	13	13.0	4	515.0	187
SEF	1982																										
Troll	1983					16.0	3	620.0	146	539.0	128	435.0	93	347.0	74	379.5	101	358.5	77	406.0	97	377.5	94	270.5	64	3749.0	877
	1984	212.0	48	171.0	46	201.0	48																	162.5	40	746.5	182
	1985	152.5	35	123.0	29	199.5	51	140.0	41	132.0	37	125.5	34	106.0	23	53.0	13	62.5	15	61.0	16	90.0	24	99.0	26	1344.0	344
Other	1982																										
	1983					0.0	0	109.0	38	91.5	30	19.5	12	48.5	22	34.5	22	11.5	7	29.5	11	28.0	15	16.5	10	388.5	167
	1984	25.5	16	62.0	20	55.0	19																	34.5	11	177.0	66
	1985	146.5	36	169.5	32	122.0	32	6.5	6	27.0	19	6.0	5	7.0	2	0.0	0	6.5	4	0.0	0	3.0	3	22.0	12	516.0	151
SF	1982																										
	1983					21.5	5	184.0	37	177.0	38	128.5	23	156.0	30	148.0	30	86.5	17	189.5	34	148.0	27	135.0	27	1374.0	268
Troll	1983	102.0	17	17.0	4	15.5	4	599.0	137	924.5	165	906.5	158	799.0	151	614.0	123	422.0	86	544.5	105	591.5	104	403.0	71	5938.5	1125
	1984	159.0	31	248.0	47	247.0	52	335.0	70	268.0	57	321.5	64	248.0	52	235.5	47	155.0	29	158.5	31	274.5	54	134.0	29	2784.0	563
	1985	213.5	42	281.5	55	247.5	52	215.0	46	340.0	60	205.0	35	204.5	38	189.0	34	64.5	12	117.5	20	79.0	15	0.0	0	2157.0	409
Other	1982					1.0	1	19.0	15	9.0	7	2.5	2	5.5	2	4.5	2	16.0	2	0.0	0	0.0	0	0.0	0	57.5	31
	1983	0.0	0	0.0	0	20.0	7	327.5	98	190.5	51	60.5	22	63.5	18	46.0	18	56.5	18	122.5	33	150.5	34	182.0	33	1219.5	332
	1984	80.5	17	48.0	20	75.5	31	28.5	16	34.0	13	0.0	0	12.0	4	0.0	0	7.5	2	0.0	0	22.5	10	1.5	1	310.0	114
	1985	0.0	0	23.0	6	44.5	20	130.5	30	89.0	23	58.0	12	43.0	11	65.5	13	88.5	17	20.5	4	101.0	17	0.0	0	663.5	153
SWF	1982																										
Troll	1983							16.0	3	0.0	0	0.0	0	0.0	0	1.5	2	4.0	1	60.5	16	4.0	1	0.0	0	86.0	23
	1984	0.0	0	0.0	0	0.0	0																	38.5	7	38.5	7
	1985	3.5	1	7.0	4	25.5	11	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0			36.0	16
Other	1982																										
	1983							449.0	90	643.0	126	566.5	107	468.5	100	403.5	97	356.5	82	319.5	74	376.0	84	277.0	62	3859.5	822
	1984	384.0	78	358.5	73	489.0	87																	164.0	37	1395.5	275
	1985	219.5	49	193.0	45	198.0	52	297.5	51	204.0	37	168.5	37	54.5	11	58.5	13	89.0	18	74.5	15	72.5	12			1629.5	340
WF	1982																										
Troll	1983					0.0	0	173.5	47	164.5	47	134.5	32	190.0	36	99.5	22	112.0	29	106.5	25	77.0	21	38.0	13	1095.5	272
	1984	18.5	6	13.5	5	19.5	8	238.0	52	161.5	42	182.0	43	255.5	59	220.0	52	113.0	29	201.5	46	116.0	29	25.0	10	1564.0	381
	1985	4.0	1	2.5	1	124.0	29	174.0	47	133.0	35	172.5	38	140.5	31	106.0	23	57.5	12	87.5	23	55.0	15	16.0	5	1072.5	260
Other	1982																										
	1983					11.0	2	144.5	33	177.5	37	216.5	45	152.5	41	219.5	56	128.5	31	105.0	25	148.5	34	113.0	27	1416.5	331
	1984	148.5	33	223.5	49	278.5	60	38.0	7	37.0	9	43.5	11	32.0	7	65.5	11	18.0	4	14.0	4	45.0	10	146.0	33	1087.5	238
	1985	64.0	15	165.5	31	155.5	34	115.5	26	78.5	20	73.0	20	84.0	23	104.5	20	83.0	16	41.0	11	80.0	16	38.0	10	1082.5	242
NWF	1982							42.5	7	83.5	15	105.5	24	77.0	19	86.5	20	118.5	21	63.0	12					576.5	118
Troll	1983					2.5	1	269.5	71	388.0	101	558.5	150	719.5	178	773.0	151	562.0	106	296.0	67	34.0	10			3603.0	835
	1984							24.0	6	19.0	7	110.0	29	102.5	25	88.5	22	79.0	17	37.0	11	10.5	3			470.5	120
	1985					2.5	1	34.0	7	34.5	9	26.0	8	116.5	28	100.0	23	44.0	7	1.5	1	0.0	0			359.0	84
Other	1982							0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0					0.0	0
	1983					7.5	2	379.0	74	602.5	117	542.0	130	587.5	126	357.5	80	438.0	88	415.0	81	120.0	20			3449.0	718
	1984							102.0	20	181.5	36	193.5	49	100.5	24	128.5	27	178.5	38	159.5	35	10.0	1			1054.0	230
	1985					41.5	9	183.0	38	236.0	50	219.0	48	192.0	38	176.0	33	157.0	36	200.5	45	70.0	15			1475.0	312
AL	1982																										
Troll	1983							55.0	11	151.0	35	231.5	56	299.0	68	253.5	62	139.5	38	130.0	40	22.0	9			1281.5	319
	1984																										
	1985							22.0	8	47.5	18	122.0	33	136.5	35	121.5	28	48.0	13	61.5	23	23.0	13	2.0	1	584.0	172
Other	1982																										
	1983							83.0	13	100.0	27	119.0	35	119.0	36	138.0	41	92.5	25	108.5	28	40.0	9			800.0	214
	1984																										
	1985							52.0	13	68.0	20	66.5	22	73.0	24	49.5	19	40.5	14	62.5	20	40.5	15	4.0	1	456.5	148
MS	1982																										
Troll	1983							16.5	3	133.0	28	126.0	30	172.0	33	163.0	35	112.0	24	26.0	5					748.5	158
	1984																										
	1985							56.0	11	125.0	23	144.0	29	176.0	35	90.5	19	50.5	12	37.5	10	30.0	8			709.5	147
Other	1982																										
	1983							6.0	1	32.0	7	17.0	4	14.0	3	10.5	3	0.0	0	15.0	4					94.5	22
	1984																										
	1985							24.0	5	70.5	9	61.0	13	20.5	7	19.5	4	24.5	6	61.0	11	31.0	7			312.0	62
LA	1982							6.0	3	30.5	14	38.5	11	115.5	21	58.5	19	44.0	11	1.5	1	8.0	3	0.0	0	302.5	83
Troll	1983	36.0	8	47.0	9	0.0	0	0.0	0	16.0	3	78.0	12	139.5	21	122.0	21	104.5	15	76.0	14	31.0	4	0.0	0	650.0	107
	1984	5.0	1	0.0	0	0.0	0	0.0	0	20.0	3	27.0	7	18.5	3	87.5	14	42.0	8	48.0	9	0.0	0	22.5	4	270.5	49
	1985	31.0	6	0.0	0	0.0	0	13.0	2	43.5	7	136.5	22	146.5	20	53.0	9	32.0	6	12.0	2	0.0	0	0.0	0	467.5	74
Other	1982							49.5	11	105.0	25	132.0	30	77.0	18	143.5	32	59.5	14	110.5	22	103.5	21	5.0	1	785.0	174
	1983	21.0	6	31.0	6	55.0	10	21.5	4	104.5	21	303.5	67	337.5	75	306.5	69	152.0	33	277.5	56	215.5	45	97.0	20	1922.5	412
	1984	86.0	19	186.0	37	282.0	52	99.5	21	227.0	40	224.0	51	241.5	54	234.0	50	159.0	36	251.5	58	219.0	50	150.5	36	2360.0	504
	1985	96.0	21	90.0	21	115.0	26	67.0	15	20.5	5	93.5	21	51.0	11	62.5	14	58.5	14	56.0	13	70.5	16	46.5	11	827.0	188
NTX	1982																										
Troll	1983							2.0	1	31.5	8	145.5	28	106.5	27	146.0	26	55.0	14	14.0	7	2.0	1	0.0	0	502.5	112
	1984																										
	1985							24.0	4	72.5	13	153.5	26	302.5	51	208.5	38	21.5	8	0.0	0	0.0	0			782.5	140

Continued on next page.

Table 3.—Continued.

Area and type of fishing	Year	Jan. H	Jan. D	Feb. H	Feb. D	Mar. H	Mar. D	Apr. H	Apr. D	May H	May D	June H	June D	July H	July D	Aug. H	Aug. D	Sept. H	Sept. D	Oct. H	Oct. D	Nov. H	Nov. D	Dec. H	Dec. D	Total H	Total D
Other	1982																										
	1983							39.0	8	62.5	14	91.5	25	167.5	35	52.5	14	86.5	18	63.0	15	37.0	8	13.0	3	612.5	140
	1984																										
	1985							4.0	1	67.0	11	0.0	0	55.0	10	90.0	22	49.5	11	24.0	4	16.5	3			306.0	62
STX Troll	1982							6.0	1	40.5	7	149.5	28	301.0	49	239.0	39	35.0	8	0.0	0					771.0	132
	1983							81.5	17	334.5	57	498.0	79	638.5	95	560.0	81	211.0	35	179.5	33	82.5	15	5.0	1	2590.5	413
	1984							40.5	8	119.0	23	184.0	28	249.5	40	197.0	35	52.0	8	16.0	4	0.0	0			858.0	146
	1985							17.5	4	144.0	29	237.5	49	508.5	102	454.0	92	37.5	9	0.0	0	0.0	0			1399.0	285
Other	1982							9.0	2	18.0	4	9.0	3	0.0	0	4.0	4	12.0	3	24.5	5					76.5	21
	1983							19.0	6	37.5	8	35.5	8	2.0	3	8.0	4	43.0	9	112.0	27	87.0	16	7.0	1	351.0	82
	1984							78.5	16	169.5	27	229.0	32	272.0	32	244.5	35	144.0	19	117.0	20	54.0	14			1308.5	195
	1985							37.5	7	74.0	17	66.0	17	43.5	19	40.0	18	22.0	6	3.5	1	0.0	0			286.5	85
US Carib. Troll	1982																										
	1983					56.0	10	168.5	30	105.0	19	195.5	37	318.0	51	341.5	51	154.5	28	166.0	32	178.5	32	70.0	13	1753.5	303
	1984	330.0	59	322.5	59	379.5	67	241.5	46	192.0	36	110.5	19	388.5	56	352.5	53	271.5	48	285.0	50	259.5	50	216.0	46	3349.0	589
	1985	429.5	78	366.5	63	414.0	71	273.0	51	294.5	54	288.0	50	225.5	35	375.0	59	215.0	40	330.0	60	300.5	56	205.0	38	3716.5	655

Table 4.—Yearly effort and CPUE by area and method of fishing for Spanish mackerel.

Area	1982 Other Hours	1982 Other CPUE	1982 Trolling Hours	1982 Trolling CPUE	1983 Other Hours	1983 Other CPUE	1983 Trolling Hours	1983 Trolling CPUE	1984 Other Hours	1984 Other CPUE	1984 Trolling Hours	1984 Trolling CPUE	1985 Other Hours	1985 Other CPUE	1985 Trolling Hours	1985 Trolling CPUE
North Carolina			1368.0	0.00	375.0	0.00	4498.5	0.10	96.5	0.01	1777.5	1.84	84.5	0.00	1637.5	0.34
South Carolina					420.0	0.00	831.5	0.52					40.0	0.02	557.5	0.44
Georgia					117.0	0.00	180.5	0.16					310.5	0.06	188.5	0.94
NE Florida					302.5	0.01	540.0	0.26					334.0	0.01	536.0	0.41
East Florida					471.5	0.00	3073.0	0.23	376.0	0.02	2268.0	0.07	511.0	0.00	1627.5	0.08
SE Florida					388.5	0.16	3749.0	0.21	177.0	0.00	746.5	0.15	514.0	0.06	1320.0	0.03
South Florida	57.5	0.00	1374.0	0.00	1219.5	0.00	5938.5	0.01	310.0	0.01	2784.0	0.02	663.5	0.00	2157.0	0.01
SW Florida					3859.5	0.05	86.0	1.27	1395.5	0.04	38.5	3.06	1629.5	0.03	36.0	1.94
West Florida					1416.5	0.25	1095.5	1.53	1087.5	0.01	1564.0	1.37	1082.5	0.05	1072.5	1.31
NW Florida			576.5	1.66	3449.0	0.00	3603.0	0.47	1054.0	0.07	470.5	0.21	1475.0	0.01	359.0	1.67
Alabama					800.0	0.00	1281.5	1.41					456.5	0.01	584.0	0.72
Mississippi					94.5	0.01	748.5	8.07					312.0	0.02	709.5	5.72
Louisiana	785.5	0.02	302.5	1.43	1922.5	0.07	650.0	3.13	2360.0	0.05	270.5	2.10	822.5	0.03	467.5	9.61
North Texas					612.5	0.03	502.5	0.45					306.0	0.11	782.5	0.23
South Texas	76.5	0.00	771.0	0.93	351.0	0.00	2590.5	0.08	1308.5	0.01	858.0	0.02	286.5	0.00	1399.0	0.02

Table 5.—Comparisons among fishing zones of yearly CPUE by area for Spanish mackerel caught by trolling. (CPUE values are arithmetic means.)

Area	1982 Zone 1	1982 Zone 2	1982 Zone 3	1982 Range test[1]	1983 Zone 1	1983 Zone 2	1983 Zone 3	1983 Range test[1]	1984 Zone 1	1984 Zone 2	1984 Zone 3	1984 Range test[1]	1985 Zone 1	1985 Zone 2	1985 Zone 3	1985 Range test[1]
NC	0.00	0.00	0.00		1.03	0.40	0.01	3 2 1	0.67	3.60	0.05	3 1 2	0.00	2.45	0.04	1 3 2
SC						0.66	0.00						0.67	0.84	0.02	3 2 1
GA						0.26	0.05						3.06	1.02	0.00	3 2 1
NEFL					0.81	0.30	0.17	3 2 1					0.11	0.81	0.19	1 3 2
EFL					0.00	3.87	0.27	1 3 2	0.00	0.00	0.12	1 2 3		1.93	0.10	
SEFL					0.16	2.70	0.03	3 1 2		0.17	0.04			1.07	0.00	
SFL		0.01	0.00		0.00	0.06	0.00	1 3 2		0.08	0.01			0.02	0.00	
SWFL					0.81	1.88				3.06				1.94		
WFL					0.00	1.61	0.18	1 3 2	0.23	1.43	0.07	3 1 2		1.40	0.19	
NWFL	4.92	0.84	0.01	3 2 1	1.63	0.42	0.08	3 2 1	0.69	0.15	0.14	3 2 1	3.99	0.28	0.10	3 2 1
AL					0.08	2.38	0.31	1 3 2					2.00	1.00	0.00	3 2 1
MS						8.02	10.50						3.20	5.80	4.11	3 1 2
LA	4.50	2.36	1.37	3 2 1	12.00	0.40	3.46	2 3 1		6.46	0.13		5.27	11.48	7.05	3 1 2
NTX						0.85	0.31							0.29	0.22	
STX	0.00	1.34	0.02	1 3 2	0.00	0.07	0.10	1 2 3		0.00	0.01		0.00	0.04	0.02	1 3 2

[1]Any two zones not underscored by the same line have significantly different means.

Table 6.—Statistical comparisons among areas of Log (CPUE + 1) of Spanish mackerel (analysis of variance and multiple range test). Any two logarithmic means not underscored by the same line are significantly different.

1982	NC	SFL	STX	LA	NWFL
Log (CPUE + 1)	0.00	0.00	0.06	0.20	0.20
CPUE	0.00	0.00	0.93	1.43	1.66

1983	SFL	NC	SEFL	STX	GA	EFL	NEFL	NWFL	NTX	SC	AL	LA	SWFL	WFL	MS
Log (CPUE + 1)	0.00	0.02	0.02	0.03	0.05	0.05	0.08	0.09	0.10	0.11	0.23	0.27	0.32	0.33	0.76
CPUE	0.01	0.10	0.21	0.08	0.16	0.23	0.26	0.47	0.45	0.52	1.41	3.13	1.27	1.53	8.07

1984	STX	SFL	EFL	SEFL	NWFL	NC	LA	WFL	SWFL
Log (CPUE + 1)	0.01	0.01	0.02	0.03	0.04	0.19	0.28	0.29	0.56
CPUE	0.02	0.02	0.07	0.15	0.21	1.84	2.10	1.37	3.06

1985	SFL	SEFL	STX	EFL	NC	NTX	SC	NEFL	AL	GA	NWFL	WFL	SWFL	MS	LA
Log (CPUE + 1)	0.00	0.01	0.01	0.02	0.03	0.07	0.08	0.10	0.17	0.18	0.15	0.25	0.43	0.71	0.77
CPUE	0.01	0.03	0.02	0.08	0.34	0.23	0.44	0.41	0.72	0.94	1.67	1.31	1.94	5.72	9.61

Table 7.—Comparison among areas of CPUE by year and zone for Spanish mackerel caught while trolling.

Year and zone	Mean CPUE by area															Area in order of increasing CPUE and results of range test[1]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1982																
1	0.00									4.92			4.50		0.00	1 15 10 13
2	0.00						0.01			0.84			2.36		1.34	1 7 15 10 13
3	0.00						0.00			0.01			1.37		0.02	1 7 10 15 13
1983																
1	1.03			0.81	0.00	0.16	0.00	0.81	0.00	1.63	0.08		12.00		0.00	5 7 9 15 11 6 4 1 8 10 13
2	0.40	0.66	0.26	0.30	3.87	2.70	0.06	1.88	1.61	0.42	2.38	8.02	0.40	0.85	0.07	7 15 1 3 10 4 13 2 14 6 5 9 11 8 12
3	0.01	0.00	0.05	0.17	0.27	0.03	0.00		0.18	0.08	0.31	10.50	3.46	0.31	0.10	2 7 1 6 3 10 15 9 4 11 14 5 13 12
1984																
1	0.67				0.00				0.23	0.69						5 9 10 1
2	3.60				0.00	0.17	0.08	3.06	1.43	0.15			6.46		0.00	5 15 7 10 6 9 1 8 13
3	0.05				0.12	0.04	0.01		0.07	0.14			0.13		0.01	7 15 6 1 9 10 5 13
1985																
1	0.00	0.67	3.06	0.11						3.99	2.00	3.20	5.27		0.00	1 15 4 2 10 11 3 12 13
2	2.45	0.84	1.02	0.81	1.93	1.07	0.02	1.94	1.40	0.28	1.00	5.80	11.48	0.29	0.04	7 15 10 14 2 4 1 6 3 11 9 5 8 12 13
3	0.04	0.02	0.00	0.19	0.10	0.00	0.00		0.19	0.10	0.00	4.11	7.05	0.22	0.02	3 11 7 6 15 1 2 10 5 4 9 14 12 13

[1]Any two areas not underscored by the same line have significantly different means.

zones 5, 6, and 7, occurred in this zone. The second most important zone in terms of trolling effort was the nearshore zone (zone 2); over 21 percent of the trolling effort each year, in addition to the contributions from zones 4, 6, and 7, occurred in this zone. The second most important zone for other fishing was in the estuarine zone; percentages of effort expended (not including the contributions from zones 4, 5, and 7) in this zone were 7.1 percent in 1982, 21.4 percent in 1983, 15.1 percent in 1984, and 15.2 percent in 1985.

Much more other-fishing effort occurred in the estuarine zone (17.9 percent) than did trolling effort (2.2 percent) based on data combined for all years (Table 2). Percentages of total effort were similar between methods for zones 2 and 3.

Fishing effort was not monitored

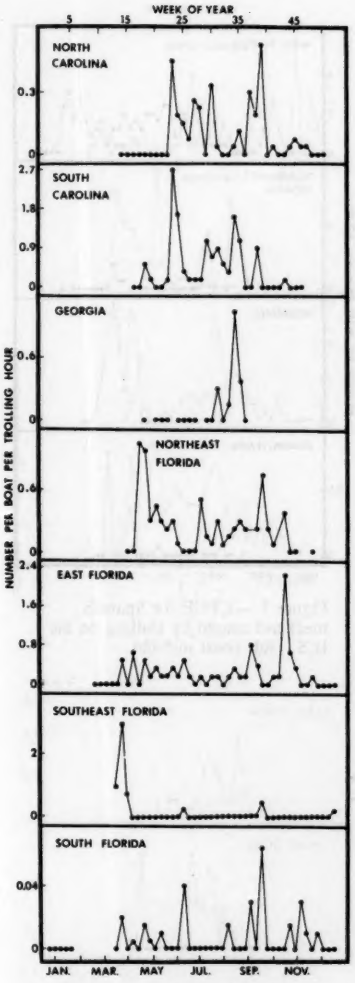

Figure 2.—CPUE for Spanish mackerel caught by trolling on the southeastern U.S. coast in 1983.

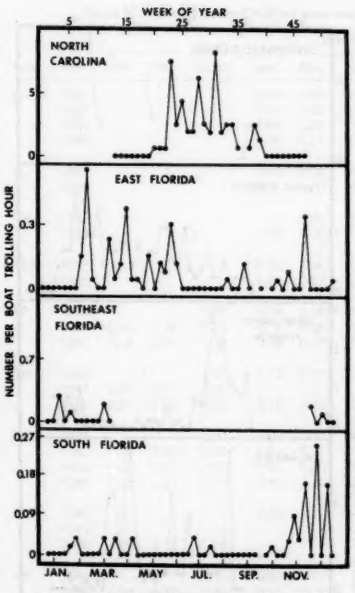

Figure 3.—CPUE for Spanish mackerel caught by trolling on the southeastern U.S. coast in 1984.

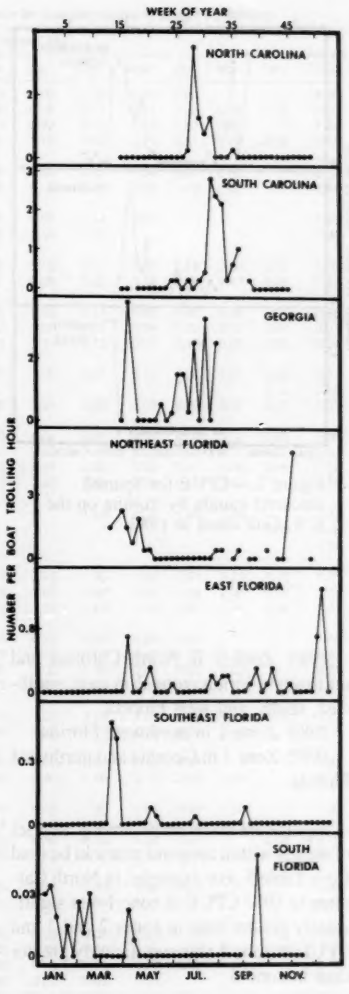

Figure 4.—CPUE for Spanish mackerel caught by trolling on the southeastern U.S. coast in 1985.

throughout the year in most areas and years (Table 3). The months of January, February, and March were not surveyed for the most part north of the east and west Florida areas (Fig. 1) except in Louisiana.

Data in Table 3 are useful to evaluate the seasonality of fishing effort because the numbers of boats in the survey remained relatively constant within an area and year with one exception. In North Carolina in 1982, during the pilot survey, two boats reported in April through July with only one boat reporting the remainder of the survey.

CPUE Comparisons

Between Fishing Methods

CPUE of Spanish mackerel by other fishing was much lower than by trolling for most areas and years (Table 4). Area-year combinations where other-fishing CPUE was at least one-fourth of trolling CPUE were southeast Florida in 1983; east, south, and northwest Florida, and south Texas in 1984; and southeast Florida and north Texas in 1985.

Among Fishing Zones

CPUE was highest in the estuarine zone in most areas and years. CPUE in each zone and area and results of comparisons among zones are provided in Table 5. Mean values of zone CPUE significantly greater than all other zone means within area and year were:

1982: Zone 1 in northwest Florida.

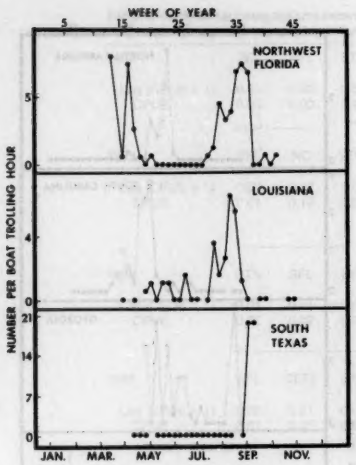

Figure 5.—CPUE for Spanish mackerel caught by trolling on the U.S. Gulf coast in 1982.

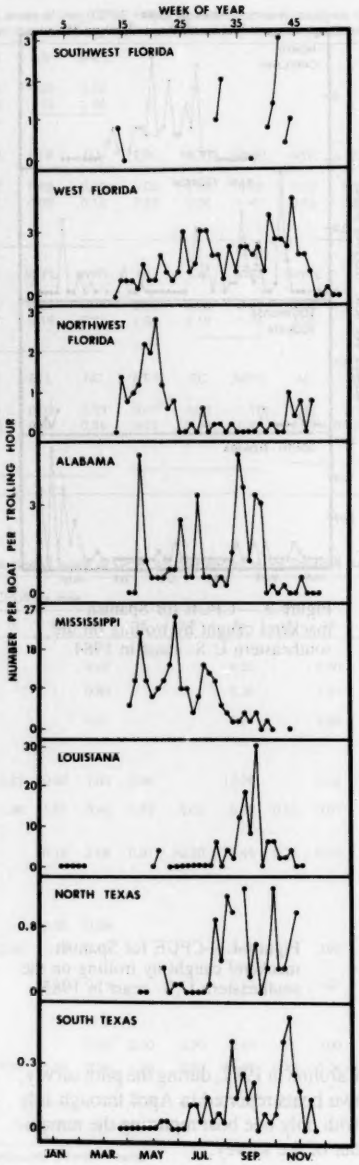

Figure 6.—CPUE for Spanish mackerel caught by trolling on the U.S. Gulf coast in 1983.

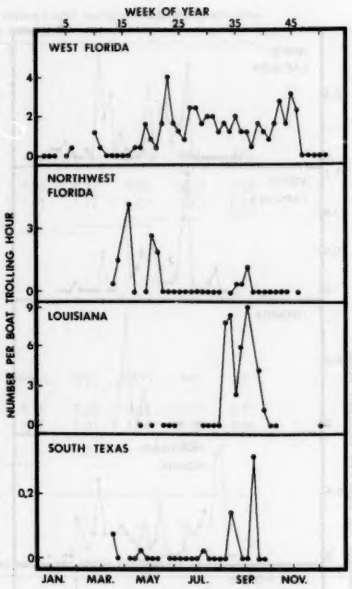

Figure 7.—CPUE for Spanish mackerel caught by trolling on the U.S. Gulf coast in 1984.

1983: Zone 1 in North Carolina and northwest Florida; zone 2 in east, southeast, south, and west Florida.

1984: Zone 1 in northwest Florida.

1985: Zone 1 in Georgia and northwest Florida.

Significant differences among any set of means within area and year can be read from Table 5. For example, in North Carolina in 1983 CPUE in zone 1 was significantly greater than in zones 2 and 3 and CPUE in zone 2 was significantly greater than in zone 3.

Among Areas

When data from all zones and all months within each year were combined, highest catch rates of Spanish mackerel occurred in the areas within the eastern Gulf of Mexico from Louisiana to southwest Florida each year (Table 6). In 1982 CPUE from Louisiana and northwest Florida were significantly higher than in the other three areas. In 1983 through 1985 CPUE was significantly higher in Mississippi (1983), in southwest Florida (1984), and in Louisiana (1985) than in the other areas.

CPUE was also compared among areas within each zone (Table 7). Area mean values of CPUE determined to be significantly greater than all other area means within zone and year were:

Zone 1: Louisiana in 1983.

Zone 2: Louisiana in 1982 and 1985; Mississippi in 1983.

Zone 3: Louisiana in 1982 and 1985; Mississippi in 1983.

Significant differences among any set of means within zone and year can be read from Table 7. For example, in zone 2 in 1984, CPUE in Louisiana was signifi-

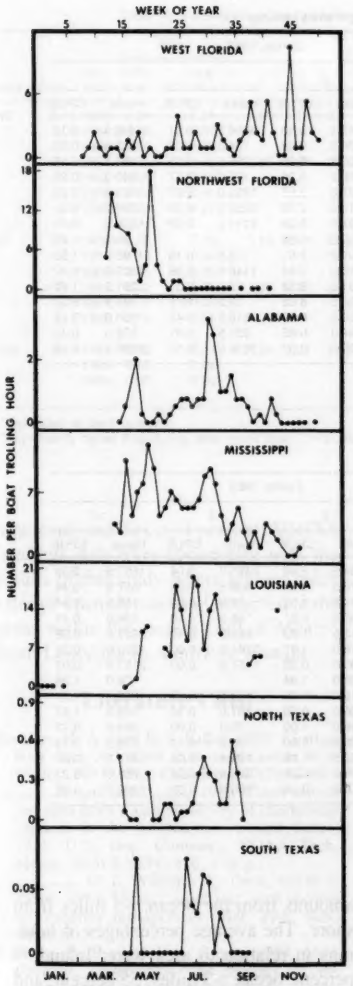

Figure 8.—CPUE for Spanish mackerel caught by trolling on the U.S. Gulf coast in 1985.

Table 8.—Monthly mean CPUE by area and year for Spanish mackerel caught by trolling.

		Monthly mean CPUE											
Area	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual CPUE
NC	1982				0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
	1983				0.00	0.00	0.19	0.20	0.01	0.21	0.02	0.03	0.00	0.10
	1984				0.04	0.32	3.07	2.92	3.41	1.48	0.27	0.00		1.84
	1985				0.00	0.01	0.01	1.18	0.44	0.13	0.01	0.00	0.00	0.34
SC	1983				0.00	0.16	1.20	0.51	0.73	0.54	0.07	0.00		0.52
	1985				0.00	0.00	0.08	0.16	1.62	0.54	0.05	0.00		0.44
GA	1983					0.00	0.00	0.00	0.44	0.00				0.16
	1985				1.50	0.00	0.45	1.49	1.95					0.94
NEF	1983				0.57	0.46	0.08	0.10	0.21	0.47	0.19	0.00	0.00	0.26
	1985				1.61	0.57	0.07	0.08	0.22	0.19	0.09	1.67	0.00	0.41
EF	1983			0.00	0.34	0.25	0.25	0.10	0.17	0.36	0.53	0.20	0.00	0.23
	1984	0.00	0.16	0.03	0.14	0.06	0.13	0.00	0.01	0.04	0.12	0.12	0.01	0.07
	1985	0.00	0.01	0.00	0.29	0.07	0.03	0.01	0.13	0.01	0.15	0.06	0.55	0.08
SEF	1983			1.60	1.10	0.00	0.03	0.00	0.01	0.11	0.01	0.02	0.05	0.21
	1984	0.41	0.03	0.06									0.10	0.15
	1985	0.00	0.00	0.00	0.18	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03
SF	1982			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
	1983	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.01
	1984	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.08	0.09	0.02
	1985	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00		0.01
SWF	1983				0.50				1.50	0.00	1.48	1.00		1.27
	1984												3.06	3.06
	1985	4.86	2.13	1.60										1.94
WF	1983				0.61	1.22	1.47	2.22	1.60	1.87	2.57	2.32	0.03	1.53
	1984	0.00	0.30	0.40	0.11	0.75	2.48	1.87	1.64	1.34	1.56	2.36	0.00	1.37
	1985	0.00	0.00	0.89	0.86	0.65	1.43	1.13	1.25	1.78	2.81	1.94	3.50	1.31
NWF	1982				2.90	0.42	0.03	0.26	2.53	5.26	0.26			1.66
	1983			0.00	1.06	1.78	0.32	0.28	0.08	0.07	0.18	0.48		0.47
	1984				1.33	1.50	0.00	0.00	0.00	0.40	0.05	0.00		0.21
	1985			4.80	11.10	5.10	1.25	0.06	0.00	0.00	0.00			1.67
AL	1983				2.80	0.94	1.20	1.26	1.76	2.91	0.23	0.33		1.41
	1985				0.58	0.14	0.42	1.20	1.70	0.51	0.31	0.00	0.00	0.72
MS	1983				12.20	9.69	14.97	10.67	3.25	2.15	0.08			8.07
	1985				6.20	8.62	5.92	6.80	5.99	2.17	2.25	0.30		5.72
LA	1982				0.00	0.54	1.16	0.00	4.02	2.04	0.00	0.00		1.43
	1983	0.00	0.00			1.40	0.04	1.86	5.40	8.04	4.01	0.25		3.13
	1984	0.00				0.00	0.00	0.00	2.50	5.72	2.45		0.00	2.10
	1985	0.00			0.00	8.16	10.93	11.12	15.72	4.97	9.83			9.61
NTX	1983				0.00	0.14	0.05	0.41	0.98	0.46	0.50	1.00		0.45
	1985				0.17	0.08	0.10	0.30	0.29	0.19				0.23
STX	1982				0.00	0.00	0.00	0.00	0.05	15.04				0.93
	1983				0.00	0.00	0.03	0.09	0.10	0.15	0.22	0.18	0.00	0.08
	1984				0.03	0.01	0.00	0.01	0.00	0.23	0.00			0.02
	1985				0.00	0.01	0.00	0.05	0.02	0.00				0.02

cantly greater than all other areas except southwest Florida. CPUE in southwest Florida and North Carolina were significantly greater than in northwest Florida, south Florida, south Texas, and east Florida.

Seasonality

Weekly estimates of CPUE were plotted to analyze abundance of Spanish mackerel through seasons in relation to area. Along the Atlantic coast the fish were abundant in the warmer months in the northerly areas (northeast Florida to North Carolina), and abundant in the colder months, or sporadically throughout the year, in the southeast areas of Florida (Fig. 2-4). In general, low CPUE in east Florida coincided with high CPUE in Georgia and the Carolinas, possibly indicating migration from the southerly to the northerly areas.

In the Gulf of Mexico, sufficient data for evaluation were obtained only from the west Florida to the south Texas area (Fig. 5-8). Spanish mackerel were abundant, as reflected by CPUE data, from May through November in west Florida; in April-May, or August-October, or both in northwest Florida, Alabama, Louisiana, and Texas; and during May-July in Mississippi.

Variation in mean CPUE among months within an area and year can be observed in Table 8. For example, mean CPUE in North Carolina in 1983 ranged

Table 9.—Yearly effort and CPUE by zone and area for Spanish mackerel caught while trolling.

	Zones, 1982								Zones, 1983							
	1		2		3		1-7		1		2		3		1-7	
Area	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE
North Carolina	4.0	0.00	64.5	0.00	1280.0	0.00	1368.0	0.00	270.5	1.03	245.5	0.40	3896.5	0.01	4498.5	0.10
South Carolina											638.5	0.66	144.5	0.00	831.5	0.52
Georgia											100.5	0.26	69.5	0.05	180.5	0.16
Northeast Florida									20.0	0.81	166.0	0.30	105.0	0.17	540.0	0.26
East Florida									7.0	0.00	35.0	3.87	1833.0	0.27	3073.0	0.23
Southeast Florida									86.0	0.16	115.0	2.70	3258.5	0.03	3749.0	0.21
South Florida			95.0	0.01	1039.5	0.00	1374.0	0.00	34.5	0.00	232.0	0.06	5111.0	0.00	5938.5	0.01
Southwest Florida									53.0	0.81	33.0	1.88			86.0	1.27
West Florida									5.5	0.00	801.0	1.61	113.5	0.18	1095.5	1.53
Northwest Florida	59.5	4.92	289.5	0.84	60.5	0.01	576.5	1.66	323.5	1.63	1210.0	0.42	1148.0	0.08	3603.0	0.47
Alabama									12.0	0.08	701.0	2.38	69.0	0.31	1281.5	1.41
Mississippi											733.5	8.02	12.0	10.5	748.5	8.07
Louisiana	2.0	4.50	7.5	2.36	282.0	1.37	302.5	1.43	5.0	12.00	23.0	0.40	518.5	3.46	650.0	3.13
North Texas											164.0	0.85	331.5	0.31	502.5	0.45
South Texas	6.0	0.00	550.0	1.34	129.5	0.02	771.0	0.93	9.0	0.00	820.0	0.07	1638.0	0.10	2590.5	0.08

Table 9.—Continued.

	Zones, 1984								Zones, 1985							
	1		2		3		1-7		1		2		3		1-7	
Area	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE
North Carolina	23.0	0.67	811.0	3.60	904.5	0.05	1777.5	1.84	7.5	0.00	134.5	2.45	1491.0	0.04	1637.5	0.34
South Carolina									14.5	0.67	172.5	0.84	339.5	0.02	557.5	0.44
Georgia									16.0	3.06	114.5	1.02	58.0	0.00	188.5	0.94
Northeast Florida									9.0	0.11	152.5	0.81	186.0	0.19	536.0	0.41
East Florida	2.0	0.00	24.0	0.00	764.5	0.12	2268.0	0.07			13.0	1.93	683.5	0.10	1627.5	0.08
Southeast Florida			6.0	0.17	646.5	0.04	746.5	0.15			18.0	1.07	1261.0	0.00	1320.0	0.03
South Florida			271.5	0.08	2064.0	0.01	2784.0	0.02			283.5	0.02	1457.5	0.00	2157.0	0.01
Southwest Florida			38.5	3.06			38.5	3.06			36.0	1.94			36.0	1.94
West Florida	13.5	0.23	1156.5	1.43	73.0	0.07	1546.0	1.37			912.0	1.40	143.5	0.19	1072.5	1.31
Northwest Florida	65.0	0.69	245.5	0.15	156.0	0.14	470.5	0.21	125.5	3.99	56.5	0.28	167.0	0.10	359.0	1.67
Alabama									2.0	2.00	148.0	1.00	75.0	0.00	584.0	0.72
Mississippi									5.0	3.20	678.0	5.80	26.5	4.11	709.5	5.72
Louisiana			75.5	6.46	184.0	0.13	270.5	2.10	11.0	5.27	222.5	11.48	199.5	7.05	467.5	9.61
North Texas											118.0	0.29	328.5	0.22	782.5	0.23
South Texas			24.0	0.00	810.0	0.01	858.0	0.02	19.0	0.00	600.0	0.04	688.0	0.02	1399.0	0.02

from zero in April, May, and December to 0.21 in September.

Among Years

The mean CPUE and associated effort data are given in Table 9, and results of the statistical comparisons among years are given in Table 10. Only in North Carolina and Louisiana were significant differences detected among years. In North Carolina, for all zones combined, CPUE was significantly higher in 1984 than in the other 3 years. In Louisiana, both in zone 3 and for all zones combined, CPUE was significantly higher in 1983 and 1985 than in 1982 and 1984.

Discussion

Charterboats account for only a small percentage of the total recreational fishing effort that is exerted in salt water in the southeastern United States. According to Marine Recreational Fisheries Statistics Surveys (MRFSS) conducted in 1979-85, the average percentages of effort, in fisherman trips by mode of fishing, were: Man-made (piers, jetties, bridges, etc.), 30 percent; beach/bank, 20 percent; party boat/charterboat, 11 percent and private boat (rental boat), 39 percent (NMFS, 1984-86).

Of the four modes of fishing, the private boat/rental boat mode produced greatest landings of Spanish mackerel. The average percentages of total landings for the 7 years by mode of fishing were: Man-made, 18 percent; beach/bank, 2 percent; party boat/charterboat, 25 percent and prviate boat (rental boat), 56 percent.

Based on the MRFSS 1979-85 data, Spanish mackerel were landed in greatest amounts from the ocean ≤3 miles from shore. The average percentages of landings in relation to area were: Inland, 9 percent; ocean ≤3 miles, 55 percent; and ocean >3 miles, 36 percent. Our data indicate that for charterboats the highest CPUE of Spanish mackerel usually occurred in the estuarine zone where the lowest landings were reported by the MRFSS, assuming that the "inland" category is the same or similar to our estuarine zone.

Greatest landings of Spanish mackerel occurred in west Florida, Alabama, and Mississippi areas when states and areas of states were compared. The average percentages of landings by area for 1979-85 were: North Carolina, 14 percent; South Carolina, 5 percent; Georgia, 1 percent; east Florida, 11 percent; west Florida, 25 percent; Alabama, 18 percent; Mississippi, 19 percent; Louisiana,

Table 10.—Comparison for Spanish mackerel of log (CPUE+1) among years for those areas, zones, and years with sufficient data.

Area	Zone	Year	Mean Arithmetic	Mean Log (CPUE+1)	F	d.f.	$F_{.10}$
NC	2	1983	1.04	0.26	0.61	2,12	2.8
		1984	3.79	0.55			
		1985	3.35	0.40			
	1-7	1982	0.00	0.00	*2.67	3,28	2.3
		1983	0.08	0.16			
		1984	1.11	**0.31			
		1985	0.22	0.07			
EF	3	1983	0.26	0.10	1.13	2,24	2.5
		1984	0.16	0.06			
		1985	0.15	0.06			
	1-7	1983	0.22	0.08	1.25	2,27	2.5
		1984	0.10	0.05			
		1985	0.13	0.05			
SEF	3	1983	0.03	0.01	2.54	2,21	2.6
		1984	0.10	0.04			
		1985	0.00	0.00			
	1-7	1983	0.29	0.09	1.68	2,24	2.5
		1984	0.09	0.03			
		1985	0.02	0.01			
WF	2	1983	1.60	0.36	0.61	2,24	2.5
		1984	1.39	0.34			
		1985	1.86	0.43			
	1-7	1983	1.55	0.41	0.46	2,24	2.5
		1984	1.35	0.34			
		1985	1.71	0.41			
NWF	1	1982	5.60	0.79	2.02	3,10	2.7
		1983	1.42	0.37			
		1984	0.82	0.20			
		1985	5.42	0.64			
	2	1982	0.95	0.23	2.04	3,20	2.4
		1983	0.42	0.13			
		1984	0.40	0.13			
		1985	0.01	0.01			
	1-7	1982	1.67	0.33	1.11	3,24	2.5
		1983	0.54	0.16			
		1984	0.30	0.10			
		1985	2.50	0.32			
LA	3	1982	1.30	0.31	*3.10	3,19	2.4
		1983	4.70	**0.60			
		1984	0.18	0.05			
		1985	8.46	**0.66			
	1-7	1982	1.11	0.29	*4.26	3,20	2.4
		1983	3.00	**0.56			
		1984	1.52	0.32			
		1985	8.68	**0.90			
STX	1-7	1982	2.52	0.21	0.89	3,20	2.4
		1983	0.06	0.03			
		1984	0.04	0.02			
		1985	0.01	0.01			

*Significant at the $F_{.10}$ level.
**Significantly higher than during other years based on Duncan's multiple range test.

4 percent; and Texas, 4 percent. MRFSS landings data were concordant with the results of this study where highest catch rates of Spanish mackerel occurred in the areas within the eastern Gulf of Mexico from Louisiana to southwest Florida.

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Abundance of King Mackerel, *Scomberomorus cavalla*, in the Southeastern United States Based on CPUE Data From Charterboats, 1982-85

LEE TRENT, BARBARA JAYNE PALKO, MARK L. WILLIAMS, and HAROLD A. BRUSHER

ABSTRACT—In 1982, a survey was initiated to obtain daily catch and effort data on fishes commonly caught by charterboats in the southeastern United States. Boat effort and king mackerel, Scomberomorus cavalla, *CPUE data obtained from 1982 through 1985 were analyzed. The offshore fishing zone (>10 fathoms) received the highest amount of trolling and other fishing (nontrolling) efforts; the nearshore fishing zone (≤10 fathoms) received the second highest trolling effort and lowest other fishing effort; the estuarine fishing zone received the lowest trolling effort and the second lowest other fishing effort. Data to evaluate seasonal fluctuations in fishing effort were provided for 15 areas of the southeastern United States and for the U.S. Caribbean. Annual CPUE of king mackerel by other fishing was much lower than trolling for most areas and years. CPUE was higher in the nearshore or offshore zone than in the estuarine zone for all area-year combinations except North Carolina in 1983. CPUE values were highest in the nearshore zone about as often as in the offshore zone. Highest catch rates occurred in areas in both the U.S. south Atlantic and Gulf of Mexico when all years were evaluated; high catch rates occurred in North Carolina, Georgia, northwest Florida, Louisiana, and Texas. Seasonal patterns of CPUE along the U.S. south Atlantic coast varied among areas in such a way as to show that a temperature-dependent migration (north in the warm months and south in the cold months) was not indicated; king mackerel were high in abundance off North Carolina and the southern areas of Florida in late fall and early winter. In the Gulf of Mexico, it appeared that in the spring and early summer some groups of king mackerel simultaneously migrated northward along the east and west Gulf of Mexico coasts. Highest CPUE for king mackerel occurred in 1983 or 1985 when all areas were considered. Evaluation of the historical data bases in northwest Florida indicated cyclical patterns of abundance over a 20-year period.*

Introduction

The king mackerel fisheries of the southeastern United States are presently being regulated under a Fishery Management Plan (FMP) of the Gulf of Mexico and South Atlantic Fishery Management Councils (1983, 1985). Basic to the formulation and use of the mackerel FMP are various commercial and recreational fisheries statistics that include estimates of total effort, total catch, and catch per unit of effort (CPUE). Historical data on total catch in the commercial fisheries, and on total catch and effort in the recreational fisheries, were analyzed and presented for king mackerel by Eldridge (1985). Detailed CPUE data for king mackerel over broad geographic areas have become available only recently. In 1982, surveys were initiated to obtain daily catch and effort data on fishes commonly caught by charterboats in the southeastern United States (Brusher et al., 1984). These surveys generated valuable CPUE data on king mackerel from 1982 through 1985. This paper compares the data among fishing methods, fishing zones, areas, weeks, years, and also with historical data generated by other surveys.

Obtaining Data

Recreational fishing data were obtained through contract with charterboat captains (Brusher et al., 1984). Data were obtained from from 9 charterboats in 5 areas in 1982 (Williams, Brusher, and Trent, 1984; Brusher et al., 1984), from 100 boats in 16 areas in 1983 (Williams, Brusher, Palko, and Trent, 1984; Brusher and Palko, 1985), from 31 boats in 9 areas in 1984 (Williams et al., 1985), and from 43 boats in 16 areas in 1985 (Brusher and Palko, 1986). In 1983, the year of highest coverage, the number of selected captains per area represented about 10 percent of the total number of charterboats fishing in 16 areas (Fig. 1).

Logbooks containing weekly log forms were provided to the captains who completed the forms using the following definitions.

1) Fishing zone: Three fishing zones, estuarine, nearshore, and offshore, were identified as defined in Table 1. These and combinations of these zones resulted in 7 categories for analysis.

2) Fishing method: "Trolling" was defined as fishing with hooks and line at any depth while the boat was moving under its own power. "Other fishing" included all other fishing methods, such as bottom fishing, drift fishing, and flylining.

3) Hours actually fished: This was the total number of hours fished by a single boat on all of its trips for one day using a particular method. Only actual fishing times, rounded to the nearest half-hour, were reported. Running times when hooks were not in the water were specifically excluded.

4) Number caught: The number of each species caught (including releases) was recorded.

Data Analysis Methods

Effort was reported in two units, a boat-fishing-day and a boat-fishing-hour. A boat-fishing-day was defined as all fishing that occurred (trolling, other fishing, or both) from a single boat in a single day. Trips were combined if more than one trip occurred in a single day. A boat-fishing-day was recorded for each method of fishing on days that both types of fishing occurred. A boat-fishing-hour was defined as the fishing that occurred

Lee Trent, Barbara Jayne Palko, and Harold A. Brusher are with the Panama City Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407. Mark L. Williams is with the Naval Coastal Systems Center, Panama City, FL 32407.

Table 1.—Fishing zones (1, 2, and 3) and combinations of fishing zones used to record and analyze catch and effort data.

Code	Zone(s)	Definition
1	Estuarine	Bays and sounds
2	Nearshore	0-10 fathoms in ocean or Gulf
3	Offshore	Beyond 10 fathoms in ocean or Gulf
4	Estuarine & nearshore	Combination of 1 & 2
5	Estuarine & offshore	Combination of 1 & 3
6	Nearshore & offshore	Combination of 2 & 3
7	Estuarine, nearshore, & offshore	Combination of 1, 2, & 3

on one boat in a single hour by a single method of fishing.

Our CPUE estimator was defined as "the number of king mackerel caught per boat-fishing-hour (CPUE)" and was computed for each boat-fishing-day for each method of fishing. The following notations were used in the computations:

$$CPUE = X_i = \frac{No.\ of\ mackerel\ caught}{Hours\ of\ fishing}$$

$$\bar{X} = Mean\ CPUE = \frac{\sum_i X_i}{n_i}$$

$$s^2 = \frac{\sum_i X^2{}_i - \left(\sum_i X_i\right)^2 \Big/ n}{n-1}$$

n = Number of boat fishing days

$s_{\bar{X}}$ = Standard error of the mean

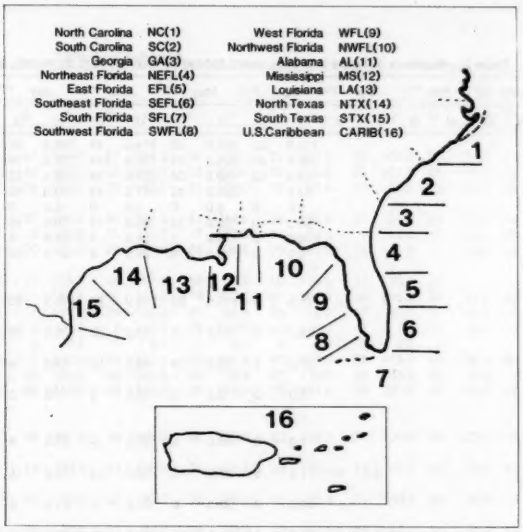

Figure 1.—Geographic areas of the charterboat survey.

$$= \sqrt{\frac{s^2}{n}} = \frac{s}{\sqrt{n}}$$

$CI_{(95\%)}$ = 95% confidence interval

$$= \bar{X} \pm t_{.05}\, s_{\bar{X}}$$

$$\text{Log CPUE} = \text{Log}_{10}\,(X_i + 1)$$

CPUE and Log CPUE were analyzed graphically (means, ranges, and standard deviations) and Log CPUE was compared among zones, areas, and years using a one-way analysis of variance with unequal replication and Duncan's multiple range test (Steel and Torrie, 1960).

CPUE data were compared among years for those areas and zones (1, 2, 3, and 1-7) where sufficient data were available. Sufficient is defined as: 1) having at

Table 2.—Sources of recreational CPUE data for king mackerel caught in southeastern U.S. waters 1965-85.

Area	Data source number	Boat type	Number months of year	Year(s) reported	Literature source	Reported unit of effort	Method of conversion to catch/boat hour	Notes
N.C.	1	Charter	8	1977	Manooch and Laws, 1979	Number of king mackerel caught per boat trip	Per trip data converted to per hour using 5.82 as divisor	Conversion factor from Table 3 (N.C. sum trolling hours/sum days)
	2	Charter	8	1978	Manooch et al., 1981	"	"	"
Dade County, Fla.	3	Charter	12	1976-77	Gentle, 1977	Number caught per boat hour, using most successful method	None	Estimates biased upward compared to estimates of this study
Panama City, Fla.	4	Charter	8	1970-71 & 73-85	Fable et al., 1981	Number of king mackerel caught per boat hour	None	Data from Capt. J. Finnegan, Jr.
	5	Charter	8	1973	Sutherland, 1977	"	None	None
	6	Charter	8	1975	Brusher et al., 1978	"	None	None
Destin, Fla.	7	Charter	8	1973-77	Fable et al., 1981	"	None	Data from Capt. A. Hilpert
Orange Beach, Ala.	8	Charter	8	1965-77	Fable et al., 1981	"	None	Data from Capt. T. Clark
Grand Isle, La.	9	Charter	12	1977-78	Fischer, 1980	Number of king mackerel caught/fisherman hour	Per fisherman data converted to per boat hour by multiplying by 5.6	None
Texas	10	Charter	12	1978-79	McEachron and Matlock, 1983	Number of king mackerel retrieved per man per trip hour	Per fisherman data converted to per boat hour by multiplying by 3.9	None
Upper Padre, Tex.	11	Inboard[1]	6	1975	Trent, 1976	Number of king mackerel caught/fisherman hour	"	None
Lower Padre, Tex.	12	Inboard	6	1975	Trent, 1976	"	"	None
Galveston, Tex.	13	Inboard	8	1976	Trent et al., 1977	"	"	None

[1]Includes charterboats and private inboard boats.

Table 3.—Numbers of hours and days spent fishing by charterboats by month, area, type of fishing, and year (H=hours and D=days).

Area and type of fishing	Year	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Total	
		H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D
NC	1982							112.0	22	261.0	40	314.0	43	358.5	51	120.0	20	120.0	20	82.5	13					1368.0	209
Troll	1983							98.0	25	508.5	89	732.0	124	782.0	134	923.0	151	689.0	114	647.0	108	111.0	20	8.0	2	4498.5	767
	1984							53.0	13	158.5	30	287.5	56	309.5	52	327.0	58	214.0	37	289.5	51	138.5	28	0.0	0	1777.5	325
	1985							33.5	7	225.0	42	257.0	46	359.5	60	305.0	49	237.0	40	131.5	29	84.0	18	5.0	2	1637.5	293
Other	1982							0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0					0.0	0
	1983							53.0	10	50.0	10	60.0	12	70.0	15	62.0	14	49.0	10	6.0	2	25.0	4	0.0	0	375.0	77
	1984							6.0	2	5.0	1	21.5	4	24.0	5	20.0	4	8.0	3	6.0	1	0.0	0	6.0	1	96.5	21
	1985							0.0	0	0.0	0	24.5	9	27.5	10	10.5	3	13.0	3	0.0	0	8.0	4	1.0	1	84.5	30
SC	1982																										
Troll	1983							18.5	4	115.5	23	119.0	23	138.5	25	194.0	30	104.0	18	96.0	17	46.0	8			831.5	148
	1984																										
	1985							16.0	3	32.0	5	92.0	20	126.0	29	132.0	24	65.0	14	64.5	19	30.0	8			557.5	122
Other	1982																										
	1983							67.0	8	64.0	14	48.0	12	43.0	9	78.0	16	120.0	13	0.0	0	0.0	0			420.0	72
	1984																										
	1985							0.0	0	0.0	0	18.0	6	7.0	3	3.0	1	6.0	2	6.0	3	0.0	0			40.0	15
GA	1982																										
Troll	1983							0.0	0	25.0	6	36.5	9	37.5	8	74.0	14	7.5	2	0.0	0	0.0	0			180.5	39
	1984																										
	1985					0.0	0	11.5	5	28.0	10	59.0	14	70.0	15	20.0	5	0.0	0	0.0	0	0.0	0			188.5	49
Other	1982																										
	1983							30.0	3	39.0	8	22.5	7	21.0	5	3.0	1	1.5	1	0.0	0	0.0	0			117.0	25
	1984																										
	1985					17.5	4	35.5	7	91.5	20	75.0	20	69.0	16	22.0	5	0.0	0	0.0	0	0.0	0			310.5	72
NEF	1982																										
Troll	1983							43.5	11	112.5	21	87.5	16	76.0	14	103.5	18	32.0	6	57.0	14	21.0	6	7.0	1	540.0	107
	1984																										
	1985					0.0	0	53.0	11	146.0	29	109.5	20	87.5	18	75.5	19	27.0	7	25.5	10	9.0	3	3.0	1	536.0	118
Other	1982																										
	1983					82.0		14	15.5	5	53.0	10	16.0	5	29.0	6	13.5	3	21.5	5	72.0	17	0.0	0		302.5	65
	1984																										
	1985					4.0	1	57.0	14	12.5	3	50.5	12	36.0	10	33.5	10	25.5	8	30.0	9	42.0	12	43.0	12	334.0	91
EF	1982																										
Troll	1983					106.5	21	323.5	86	348.0	89	369.0	97	459.0	116	494.0	120	300.0	73	226.5	63	244.0	63	202.5	43	3073.0	771
	1984	263.5	46	250.0	44	243.0	41	330.5	71	169.5	49	180.0	50	194.0	47	221.0	49	95.0	24	96.5	30	95.5	26	129.5	26	2268.0	503
	1985	183.0	30	203.0	39	273.0	49	124.0	33	159.0	44	148.5	43	172.0	54	130.0	33	56.0	15	71.5	22	80.5	25	30.0	11	1630.5	398
Other	1982																										
	1983					8.0	2	85.5	36	65.5	34	85.5	40	76.5	30	50.0	23	55.5	15	27.5	11	14.5	11	3.0	4	471.5	206
	1984	1.5	3	24.5	12	28.5	15	47.0	26	56.0	20	49.0	19	30.0	14	27.5	18	22.5	12	36.5	11	26.0	10	27.0	8	376.0	168
	1985	18.0	6	36.0	12	65.5	16	18.5	11	51.0	26	45.5	25	85.0	35	27.0	12	36.5	10	69.0	17	50.0	13	13.0	4	515.0	187
SEF	1982																										
Troll	1983					16.0	3	620.0	146	539.0	128	435.0	93	347.0	74	379.5	101	358.5	77	406.0	97	377.5	94	270.5	64	3749.0	877
	1984	212.0	48	171.0	46	201.0	48																	162.5	40	746.5	182
	1985	152.5	35	123.0	29	199.5	51	140.0	41	132.0	37	125.5	34	106.0	23	53.0	13	62.5	15	61.0	16	90.0	24	99.0	26	1344.0	344
Other	1982																										
	1983					0.0	0	109.0	38	91.5	30	19.5	12	48.5	22	34.5	22	11.5	7	29.5	11	28.0	15	16.5	10	388.5	167
	1984	25.5	16	62.0	20	55.0	19																	34.5	11	177.0	66
	1985	146.5	36	169.5	32	122.0	32	6.5	6	27.0	19	6.0	5	7.0	2	0.0	0	6.5	4	0.0	0	3.0	3	22.0	12	516.0	151
SF	1982					21.5	5	184.0	37	177.0	38	128.5	23	156.0	30	148.0	30	86.5	17	189.5	34	148.0	27	135.0	27	1374.0	268
Troll	1983	102.0	17	17.0	4	15.5	4	599.0	137	924.5	165	906.5	158	799.0	151	614.0	123	422.0	86	544.5	105	591.5	104	403.0	71	5938.5	1125
	1984	159.0	31	248.0	47	247.0	52	335.0	70	268.0	57	321.5	64	248.0	52	235.5	47	155.0	29	158.5	31	274.5	54	134.0	29	2784.0	563
	1985	213.5	42	281.5	55	247.5	52	215.0	46	340.0	60	205.0	35	204.5	38	189.0	34	64.5	12	117.5	20	79.0	15	0.0	0	2157.0	409
Other	1982					1.0	1	19.0	15	9.0	7	2.5	2	5.5	2	4.5	2	16.0	2	0.0	0	0.0	0	0.0	0	57.5	31
	1983	0.0	0	0.0	0	20.0	7	327.5	98	190.5	51	60.5	22	63.5	18	46.0	18	56.5	18	122.5	33	150.5	34	182.0	33	1219.5	332
	1984	80.5	17	48.0	20	75.5	31	28.5	16	34.0	13	0.0	0	12.0	4	0.0	0	7.5	2	0.0	0	22.5	10	1.5	1	310.0	114
	1985	0.0	0	23.0	6	44.5	20	130.5	30	89.0	23	58.0	12	43.0	11	65.5	13	88.5	17	20.5	4	101.0	17	0.0	0	663.5	153
SWF	1982																										
Troll	1983							16.0	3	0.0	0	0.0	0	0.0	0	1.5	2	4.0	1	60.5	16	4.0	1	0.0	0	86.0	23
	1984	0.0	0	0.0	0	0.0	0																	38.5	7	38.5	7
	1985	3.5	1	7.0	4	25.5	11	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0			36.0	16
Other	1982																										
	1983							449.0	90	643.0	126	566.5	107	468.5	100	403.5	97	356.5	82	319.5	74	376.0	84	277.0	62	3859.5	822
	1984	384.0	78	358.5	73	489.0	87																	164.0	37	1395.5	275
	1985	219.5	49	193.0	45	198.0	52	297.5	51	204.0	37	168.5	37	54.5	11	58.5	13	89.0	18	74.5	15	72.5	12			1629.5	340

Continued on next page.

least 4 monthly means within each year and at least 3 years of data for a particular area and zone, 2) having excluded months in which all values were zero, and 3) having at least one annual mean (arithmetic) greater than 0.1 within the set to be compared. The monthly mean of log (CPUE + 1) was used as the observation. Arithmetic means are reported even when the statistical comparisons were made on the log values.

CPUE estimates from some other surveys were reported in effort units other than number caught per boat-fishing-hour (Table 2). For these surveys, the data were transformed to our CPUE base before interpretation and comparison. In North Carolina, Manooch and Laws (1979) and Manooch et al. (1981) reported CPUE as the number of fish caught per trip. These data were converted to our CPUE base by dividing by 5.82, the average duration of the trolling time per trip in North Carolina as deter-

Table 3.—Continued.

Area and type of fishing	Year	Jan. H	Jan. D	Feb. H	Feb. D	Mar. H	Mar. D	Apr. H	Apr. D	May H	May D	June H	June D	July H	July D	Aug. H	Aug. D	Sept. H	Sept. D	Oct. H	Oct. D	Nov. H	Nov. D	Dec. H	Dec. D	Total H	Total D
WF	1982																										
Troll	1983					0.0	0	173.5	47	164.5	47	134.5	32	190.0	36	99.5	22	112.0	29	106.5	25	77.0	21	38.0	13	1095.5	272
	1984	18.5	6	13.5	5	19.5	8	238.0	52	161.5	42	182.0	43	255.5	59	220.0	52	113.0	29	201.5	48	116.0	29	25.0	10	1564.0	381
	1985	4.0	1	2.5	1	124.0	29	174.0	47	133.0	35	172.5	38	140.5	31	106.0	23	57.5	12	87.5	23	55.0	15	16.0	5	1072.5	260
Other	1982																										
	1983					11.0	2	144.5	33	177.5	37	216.5	45	152.5	41	219.5	56	128.5	31	105.0	25	148.5	34	113.0	27	1416.5	331
	1984	146.5	33	223.5	49	278.5	60	38.0	7	37.0	9	43.5	11	32.0	7	65.5	11	18.0	4	14.0	4	45.0	10	146.0	33	1087.5	238
	1985	64.0	15	165.5	31	155.5	34	115.5	26	78.5	20	73.0	20	84.0	23	104.5	20	83.0	16	41.0	11	80.0	16	38.0	10	1082.5	242
NWF	1982							42.5	7	83.5	15	105.5	24	77.0	19	86.5	20	118.5	21	63.0	12					576.5	118
Troll	1983					2.5	1	269.5	71	388.0	101	558.5	150	719.5	178	773.0	151	562.0	106	296.0	67	34.0	10			3603.0	835
	1984							24.0	6	19.0	7	110.0	29	102.5	25	88.5	22	79.0	17	37.0	11	10.5	3			470.5	120
	1985					2.5	1	34.0	7	34.5	9	26.0	8	116.5	28	100.0	23	44.0	7	1.5	1	0.0	0			359.0	84
Other	1982							0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0					0.0	0
	1983					7.5	2	379.0	74	602.5	117	542.0	130	587.5	126	357.5	80	438.0	88	415.0	81	120.0	20			3449.0	718
	1984							102.0	20	181.5	36	193.5	49	100.5	24	128.5	27	178.5	38	159.5	35	10.0	1			1054.0	230
	1985					41.5	9	183.0	38	236.0	50	219.0	48	192.0	38	176.0	33	157.0	36	200.5	45	70.0	15			1475.0	312
AL	1982																										
Troll	1983							55.0	11	151.0	35	231.5	56	299.0	68	253.5	62	139.5	38	130.0	40	22.0	9			1281.5	319
	1984																										
	1985							22.0	8	47.5	18	122.0	33	136.5	35	121.5	28	48.0	13	61.5	23	23.0	13	2.0	1	584.0	172
Other	1982																										
	1983							83.0	13	100.0	27	119.0	35	119.0	36	138.0	41	92.5	25	108.5	28	40.0	9			800.0	214
	1984																										
	1985							52.0	13	68.0	20	66.5	22	73.0	24	49.5	19	40.5	14	62.5	20	40.5	15	4.0	1	456.5	148
MS	1982																										
Troll	1983							16.5	3	133.0	28	126.0	30	172.0	33	163.0	35	112.0	24	26.0	5					748.5	158
	1984																										
	1985							56.0	11	125.0	23	144.0	29	176.0	35	90.5	19	50.5	12	37.5	10	30.0	8			709.5	147
Other	1982																										
	1983							6.0	1	32.0	7	17.0	4	14.0	3	10.5	3	0.0	0	15.0	4					94.5	22
	1984																										
	1985							24.0	5	70.5	9	61.0	13	20.5	7	19.5	4	24.5	6	61.0	11	31.0	7			312.0	62
LA	1982							6.0	3	30.5	14	38.5	11	115.5	21	58.5	19	44.0	11	1.5	1	8.0	3	0.0	0	302.5	83
Troll	1983	36.0	8	47.0	9	0.0	0	0.0	0	16.0	3	78.0	12	139.5	21	122.0	21	104.5	15	76.0	14	31.0	4	0.0	0	650.0	107
	1984	5.0	1	0.0	0	0.0	0	0.0	0	20.0	3	27.0	7	18.5	3	87.5	14	42.0	8	48.0	9	0.0	0	22.5	4	270.5	49
	1985	31.0	6	0.0	0	0.0	0	13.0	2	43.5	7	136.5	22	146.5	20	53.0	9	32.0	6	12.0	2	0.0	0	0.0	0	467.5	74
Other	1982							49.5	11	105.0	25	132.0	30	77.0	18	143.5	32	59.5	14	110.5	22	103.5	21	5.0	1	785.0	174
	1983	21.0	6	31.0	6	55.0	10	21.5	4	104.5	21	303.5	67	337.5	75	306.5	69	152.0	33	277.5	56	215.5	45	97.0	20	1922.5	412
	1984	86.0	19	186.0	37	282.0	52	99.5	21	227.0	40	224.0	51	241.5	54	234.0	50	159.0	36	251.5	58	219.0	50	150.5	36	2360.0	504
	1985	96.0	21	90.0	21	115.0	26	67.0	15	20.5	5	93.5	21	51.0	11	62.5	14	58.5	14	56.0	13	70.5	16	46.5	11	827.0	188
NTX	1982																										
Troll	1983							2.0	1	31.5	8	145.5	28	106.5	27	146.0	26	55.0	14	14.0	7	2.0	1	0.0	0	502.5	112
	1984																										
	1985							24.0	4	72.5	13	153.5	26	302.5	51	208.5	38	21.5	8	0.0	0	0.0	0			782.5	140
Other	1982																										
	1983							39.0	8	62.5	14	91.5	25	167.5	35	52.5	14	86.5	18	63.0	15	37.0	8	13.0	3	612.5	140
	1984																										
	1985							4.0	1	67.0	11	0.0	0	55.0	10	90.0	22	49.5	11	24.0	4	16.5	3			306.0	62
STX	1982							6.0	1	40.5	7	149.5	28	301.0	49	239.0	39	35.0	8	0.0	0					771.0	132
Troll	1983							81.5	17	334.5	57	498.0	79	638.5	95	560.0	81	211.0	35	179.5	33	82.5	15	5.0	1	2590.5	413
	1984							40.5	8	119.0	23	184.0	28	249.5	40	197.0	35	52.0	8	16.0	4	0.0	0			858.0	146
	1985							17.5	4	144.0	29	237.5	49	508.5	102	454.0	92	37.5	9	0.0	0	0.0	0			1399.0	285
Other	1982							9.0	2	18.0	4	9.0	3	0.0	0	4.0	4	12.0	3	24.5	5					76.5	21
	1983							19.0	6	37.5	8	35.5	8	2.0	3	8.0	4	43.0	9	112.0	27	87.0	16	7.0	1	351.0	82
	1984							78.5	16	169.5	27	229.0	32	272.0	32	244.5	35	144.0	19	117.0	20	54.0	14			1308.5	195
	1985							37.5	7	74.0	17	66.0	17	43.5	19	40.0	18	22.0	6	3.5	1	0.0	0			286.5	85
US Carib.	1982																										
Troll	1983					56.0	10	168.5	30	105.0	19	195.5	37	318.0	51	341.5	51	154.5	28	166.0	32	178.5	32	70.0	13	1753.5	303
	1984	330.0	59	322.5	59	379.5	67	241.5	46	192.0	36	110.5	19	388.5	56	352.5	53	271.5	48	285.0	50	259.5	50	216.0	46	3349.0	589
	1985	429.5	78	366.5	63	414.0	71	273.0	51	294.5	54	288.0	50	225.5	35	375.0	59	215.0	40	330.0	60	300.5	56	205.0	38	3716.5	655

mined from 4 years of data (Table 3). Fischer (1980) reported CPUE on a catch-per-fisherman-hour basis for Louisiana as did McEachron and Matlock (1983), Trent (1976), and Trent et al. (1977) for Texas. These data were converted to our CPUE base by multiplying by 5.6 and 3.9, the average numbers of fishermen per boat in Louisiana and Texas, respectively.

Distribution of Fishing Effort Among Habitats and Months

Fishing effort among zones 1-3 (Table 1) was evaluated to determine where most of the charterboat fishing effort occurred by each method of fishing (Table 4). The offshore zone (zone 3) with water depths >10 fm received the highest amount of effort; each year over 48 percent of the trolling or other fishing effort (in addition to the contributions from zones 5, 6, and 7) occurred in this zone. The second most important zone in terms of trolling effort was the nearshore zone (zone 2); over 21 percent of the trolling effort each year (in addition to the contributions from zones 4, 6, and 7) occurred in this zone. The second most important zone for other fishing was in the estuarine

zone; percentages of effort expended (not including the contributions from zones 4, 5, and 7) in this zone were: 7.1 percent in 1982, 21.4 percent in 1983, 15.1 percent in 1984, and 15.2 percent in 1985.

Much more other-fishing effort occurred in the estuarine zone (17.9 percent) than did trolling effort (2.2 percent) based on data combined for all years (Table 4). Percentages of total effort were similar between methods for zones 2 and 3.

Fishing effort was not monitored throughout the year in most areas and years (Table 3). The months of January, February, and March were not surveyed for the most part north of the east and west Florida areas (Fig. 1) except in Louisiana.

The number of areas varied considerably among years (Table 3). Only in 1983 and 1985 were all 16 areas surveyed using the contractual procedures described by Brusher et al. (1984). Volunteered data were obtained, however, in 1984 from northeast Florida, Alabama, and Mississippi and were used to evaluate seasonal abundance of king mackerel in these areas.

Data in Table 3 are useful to evaluate the seasonality of fishing effort because the numbers of boats in the survey remained relatively constant within an area and year with one exception. In North Carolina in 1982, during the pilot survey, two boats reported from April through July and only one boat reported the remainder of the survey.

CPUE Comparisons

Between Fishing Methods

CPUE of king mackerel by other fishing was much lower than by trolling for most areas and years (Table 5). Area-year combinations where other-fishing CPUE was at least one-fourth of trolling CPUE were Georgia in 1983 and 1985; south Florida in 1983, 1984, and 1985; Louisiana in all 4 years; north Texas in 1985; and south Texas in 1984.

CPUE by other fishing was higher than trolling in some months for some areas and years (Table 6). Those areas and years were: Northwest Florida and Louisiana in 1982; Georgia, northeast, south, and southwest Florida, Mississippi, and north Texas in 1983; south Florida, Louisiana, and south Texas in 1984; and North Carolina, southeast, south, and northwest Florida, and Mississippi in 1985.

Table 4.—Number of boat fishing days expended by fishing zone, method of fishing, and year.

Year and method of fishing	Variable	Fishing zone 1	2	3	4	5	6	7	Total
1982 Trolling	No. of boat days	15	204	499	22		70		810
	Percent of total	1.8	25.2	61.6	2.7		8.6		
Other	No. of boat days	16	9	199			2		226
	Percent of total	7.1	4.0	88.1			0.9		
	Subtotal	31	213	698	22		72		1,036
	Percent	3.0	20.6	67.4	2.1		6.9		
1983 Trolling	No. of boat days	207	1,367	3,864	66	5	864	3	6,376
	Percent of total	3.2	21.4	60.6	1.0	0.0	13.6	0.0	
Other	No. of boat days	790	701	1,781	87	4	321	1	3,685
	Percent of total	21.4	19.0	48.3	2.4	0.1	8.7	0.0	
	Subtotal	997	2,068	5,645	153	9	1,185	4	10,061
	Percent	9.9	20.6	56.1	1.5	0.0	11.8	0.0	
1984 Trolling	No. of boat days	25	639	1,751	8	1	440	1	2,865
	Percent of total	0.9	22.3	61.1	0.3	0.0	15.4	0.0	
Other	No. of boat days	274	248	1,231	22	1	35		1,811
	Percent of total	15.1	13.7	68.0	1.2	0.1	1.9		
	Subtotal	299	887	2,982	30	2	475	1	4,676
	Percent	6.4	19.0	63.8	1.7	0.0	10.2	0.0	
1985 Trolling	No. of boat days	55	901	2,104	14	77	415		3,566
	Percent of total	1.5	25.3	59.0	0.4	2.2	11.6		
Other	No. of boat days	324	514	1,206	19	3	72		2,138
	Percent of total	15.2	24.0	56.4	0.9	0.1	3.4		
	Subtotal	379	1,415	3,310	33	80	487		5,704
	Percent	6.6	24.8	58.0	0.6	1.4	8.5		
1982-85 Trolling	No. of boat days	302	3,111	8,218	110	83	1,789	4	13,617
	Percent of total	2.2	22.8	60.4	0.8	0.6	13.1	0.0	
Other	No. of boat days	1,404	1,472	4,417	128	8	430	1	7,860
	Percent of total	17.9	18.7	56.2	1.6	0.1	5.5	0.0	
	Total	1,706	4,583	12,635	238	91	2,219	5	21,477
	Percent	7.9	21.3	58.8	1.1	0.4	10.3	0.0	

Among Fishing Zones

CPUE was higher in the nearshore or offshore zone than in the estuarine zone for all area-year combinations except North Carolina in 1983 (Table 7). Most of the fish reported from the estuarine zone in North Carolina in 1983 were actually caught in, and just inside, the tidal inlets of the outer banks.

CPUE values were highest in the nearshore zone about as often as in the offshore zone when all values were compared (Table 7). There was a distinct trend through the period 1982-85, however, for CPUE to become higher in the nearshore than in the offshore zone.

Table 5.—Yearly effort and CPUE by area and method of fishing for king mackerel.

	1982				1983				1984				1985			
	Other		Trolling		Other		Trolling		Other		Trolling		Other		Trolling	
Area	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE	Hours	CPUE
North Carolina	0.0		1368.0	0.40	375.0	0.04	4498.5	0.71	96.5	0.13	1777.5	1.16	84.5	0.05	1637.5	1.41
South Carolina					420.0	0.00	831.5	0.65					40.0	0.02	557.5	1.24
Georgia					117.0	0.47	180.5	0.58					310.5	0.29	188.5	1.03
NE Florida					302.5	0.05	540.0	0.38					334.0	0.04	536.0	0.51
E Florida					471.5	0.06	3073.0	1.48	376.0	0.01	2268.0	0.51	511.0	0.01	1627.5	0.64
SE Florida					388.5	0.03	3749.0	0.34	177.0	0.00	746.5	0.11	514.0	0.01	1320.0	0.19
S Florida	57.5	0.00	1374.0	0.11	1219.5	0.33	5938.5	0.10	310.0	1.42	2784.0	0.19	663.5	0.16	2157.0	0.33
SW Florida					3859.5	0.00	86.0	0.01	1395.5	0.00	38.5	0.00	1629.5	0.00	36.0	0.00
W Florida					1416.5	0.01	1095.5	0.40	1087.5	0.00	1564.0	0.36	1082.5	0.04	1072.5	0.39
NW Florida	0.0		576.5	0.72	3449.0	0.03	3603.0	1.22	1054.0	0.17	470.5	0.76	1475.0	0.09	359.0	0.56
Alabama					800.0	0.00	1281.5	0.47					456.5	0.01	584.0	0.50
Mississippi					94.5	0.05	748.5	0.15					312.0	0.03	709.5	0.36
Louisiana	785.5	0.52	302.5	0.13	1922.5	0.48	650.0	0.90	2360.0	0.45	270.5	0.90	822.5	0.30	467.5	0.90
N Texas					612.5	0.21	502.5	2.14					306.0	0.45	782.5	1.49
S Texas	76.5	0.00	771.0	1.30	351.0	0.02	2590.5	0.70	1308.5	1.05	858.0	0.26	286.5	0.19	1399.0	1.16
US Caribbean					0.0		1753.5	0.04	0.0		3349.0	0.11	0.0		3677.5	0.11

CPUE was higher in the nearshore than the offshore in 1 of 5 areas in 1982, 5 of 14 areas in 1983, 5 of 7 areas (1 tie) in 1984, and 10 of 14 areas in 1985.

Only eight of the 27 statistical comparisons of CPUE among the three zones were significant (Table 7). Mean values of zone CPUE significantly greater in zone 3 than in the other two zones were: 1982, northwest Florida; 1983, east and northwest Florida; 1984, northwest Florida; and 1985, northeast Florida. Significant differences among any set of means within area and year can be read from Table 7. For example, in Georgia in 1985 zone 3 was significantly greater than zone 1 but not zone 2.

Among Areas

High catch rates of king mackerel occurred in areas in both the Gulf of Mexico and south Atlantic each year except 1982 (Table 8). In 1982 CPUE from south Texas was significantly higher than CPUE in the other four areas. In 1983, CPUE was significantly higher in north Texas than in the other 15 areas and significantly higher in east Florida than in the remaining 14 areas. In 1984, CPUE's in Louisiana, northwest Florida, and North Carolina were significantly higher than in all other areas except east Florida. In 1985, CPUE's were significantly higher in north Texas, South Carolina, and south Texas than in all other areas except Georgia and Louisiana.

CPUE was also compared among areas within each zone (Table 9). Area mean values of CPUE determined significantly greater than all other area means within the zone and year were: Zone 1, North

Table 6.—Monthly mean CPUE by area, method, and year for king mackerel.

Year	Area and type of fishing	Monthly mean CPUE											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1982	North Carolina												
	Other fishing						0.00	0.00	0.00	0.50		0.00	0.00
	Trolling				0.03	0.41	0.07	0.02	0.02	0.04	4.67		
	S Florida												
	Other fishing			0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	Trolling			0.03	0.04	0.00	0.00	0.01	0.19	0.02	0.00	0.06	0.79
	NW Florida												
	Other fishing			0.01	0.00	0.09	0.01	0.06	0.04	0.04	0.29	0.38	
	Trolling			0.00	0.00	0.05	0.10	0.58	1.11	0.50	0.67		
	Louisiana												
	Other fishing				0.20	0.05	0.54	0.24	0.19	0.35	1.00	1.56	1.60
	Trolling				0.00	0.18	0.11	0.02	0.23	0.04	0.00	0.47	
	S Texas												
	Other fishing				0.00	0.00	0.03	0.36	0.49	0.00	0.00		
	Trolling				0.29	0.90	0.29	1.45	1.40	1.39			
1983	North Carolina												
	Other fishing				0.00	0.00	0.08	0.00	0.00	0.08	0.67	0.00	
	Trolling				0.03	1.08	0.34	0.14	0.09	0.34	2.59	2.65	1.17
	South Carolina												
	Other fishing				0.00	0.00	0.00	0.00	0.00	0.00			
	Trolling				0.82	0.90	0.29	0.19	0.31	1.04	1.50	0.85	
	Georgia												
	Other fishing				0.28	0.08	0.20	1.32	2.33	0.00			
	Trolling					0.45	0.55	0.88	0.47	0.60			
	NE Florida												
	Other fishing				0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	
	Trolling				0.09	0.59	0.62	0.42	0.28	0.18	0.19	0.00	2.14
	E Florida												
	Other fishing			0.00	0.07	0.06	0.00	0.09	0.01	0.20	0.11	0.00	0.00
	Trolling	0.07		0.36	1.25	1.19	1.27	0.96	2.12	1.52	1.19	3.06	1.14
	SE Florida												
	Other fishing				0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
	Trolling			0.00	0.12	0.18	0.12	0.16	0.52	0.36	0.73	0.65	0.43
	S Florida												
	Other fishing			0.02	0.04	0.02	0.00	0.00	0.13	0.04	0.23	0.43	2.39
	Trolling	0.56	1.38	0.00	0.02	0.01	0.00	0.01	0.03	0.01	0.13	0.34	0.55
	SW Florida												
	Other fishing				0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01
	Trolling				0.00				0.00	0.00	0.02	0.00	
	W Florida												
	Other fishing			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.00
	Trolling				0.40	0.30	0.28	0.18	0.17	0.10	0.19	0.49	3.01
	NW Florida												
	Other fishing			0.00	0.00	0.00	0.00	0.04	0.06	0.08	0.01	0.01	
	Trolling			0.00	0.00	0.02	0.31	1.63	2.73	2.10	0.61	0.05	
	Alabama												
	Other fishing				0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	
	Trolling				0.00	0.07	0.13	0.82	0.79	0.74	0.17	0.00	
	Mississippi												
	Other fishing				0.00	0.05	0.00	0.00	0.27		0.00		
	Trolling				0.00	0.00	0.00	0.00	0.41	0.30	0.55		
	Louisiana												
	Other fishing	0.00	1.97	1.52	0.09	0.05	0.07	2.25	0.36	0.23	0.77	0.64	2.02
	Trolling	2.10	2.46			0.00	0.00	0.00	0.41	1.70	1.30	1.23	
	N Texas												
	Other fishing				0.00	0.09	0.74	0.16	0.13	0.15	0.00	0.02	0.00
	Trolling				0.50	0.87	2.45	3.01	2.67	0.84	0.14	0.00	

Continued on next page.

Table 6.—Continued.

Year	Area and type of fishing	Monthly mean CPUE											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1983	S Texas												
	Other fishing				0.00	0.11	0.03	0.00	0.00	0.00	0.03	0.00	0.00
	Trolling				0.16	0.23	0.59	0.84	1.10	1.07	0.51	0.21	0.20
	US Caribbean												
	Other fishing												
	Trolling			0.00	0.03	0.02	0.02	0.04	0.02	0.06	0.07	0.06	0.08
1984	North Carolina												
	Other fishing				0.00	0.00	0.08	0.00	0.00	0.00	0.33		2.00
	Trolling				10.59	1.98	0.58	0.08	0.29	0.37	1.48	1.31	
	E Florida												
	Other fishing	0.00	0.00	0.00	0.01	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00
	Trolling	0.87	0.49	0.08	0.25	0.54	0.72	0.77	0.69	0.57	0.27	0.50	0.24
	SE Florida												
	Other fishing	0.00	0.00	0.00									0.00
	Trolling	0.26	0.04	0.03									0.08
	S Florida												
	Other fishing	3.60	3.06	1.22	0.00	0.00		0.00		0.00		0.13	0.00
	Trolling	1.16	0.71	0.22	0.03	0.00	0.02	0.02	0.04	0.03	0.06	0.15	0.14
	SW Florida												
	Other fishing	0.00	0.00	0.00									0.00
	Trolling												0.00
	W Florida												
	Other fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Trolling	0.00	0.00	0.35	1.87	0.43	0.12	0.01	0.01	0.03	0.14	0.18	0.00
	NW Florida												
	Other fishing				0.00	0.00	0.01	0.06	0.03	0.50	0.48	1.40	
	Trolling				0.00	0.17	0.19	1.38	0.77	0.69	1.54	1.43	
	Louisiana												
	Other fishing	0.61	0.35	0.29	0.13	0.00	0.09	0.50	0.44	0.61	0.72	0.66	0.99
	Trolling	0.80				0.29	0.00	0.00	0.16	0.80	2.49		2.91
	S Texas												
	Other fishing				0.21	0.36	0.49	2.42	2.41	0.74	0.01	0.02	
	Trolling				0.03	0.13	0.22	0.22	0.53	0.20	0.00		
	US Caribbean												
	Other fishing												
	Trolling	0.20	0.18	0.09	0.07	0.05	0.11	0.11	0.07	0.13	0.06	0.10	0.11
1985	North Carolina												
	Other fishing						0.00	0.00	0.00	0.50		0.00	0.00
	Trolling				6.82	1.28	0.39	0.45	0.29	0.42	2.86	8.00	4.67
	South Carolina												
	Other fishing						0.00	0.11	0.00	0.00	0.00		
	Trolling				1.30	0.00	0.85	1.01	0.76	1.02	2.81	1.95	
	Georgia												
	Other fishing			0.00	0.29	0.47	0.36	0.15	0.07				
	Trolling				0.70	1.31	1.27	1.07	0.00				
	NE Florida												
	Other fishing			0.00	0.00	0.00	0.14	0.15	0.02	0.00	0.00	0.00	0.00
	Trolling				0.38	0.61	0.89	0.67	0.43	0.00	0.02	0.00	0.00
	E Florida												
	Other fishing	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00
	Trolling	0.17	0.11	0.20	0.40	1.02	1.05	1.18	0.74	1.05	0.40	0.53	0.61
	SE Florida												
	Other fishing	0.01	0.01	0.02	0.00	0.01	0.00	0.00		0.00		0.00	0.00
	Trolling	0.01	0.02	0.00	0.12	0.41	0.43	0.27	0.15	0.33	0.46	0.15	0.20
	S Florida												
	Other fishing		0.00	0.01	0.05	0.02	0.06	0.09	0.44	0.26	0.04	0.62	
	Trolling	0.88	1.51	0.12	0.02	0.04	0.01	0.00	0.06	0.00	0.02	0.08	
	SW Florida												
	Other fishing	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	
	Trolling	0.00	0.00	0.00									
	W Florida												
	Other fishing	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Trolling	0.00	0.00	0.85	1.39	0.19	0.01	0.04	0.03	0.00	0.03	0.06	0.00
	NW Florida												
	Other fishing			0.01	0.00	0.09	0.01	0.06	0.04	0.04	0.29	0.38	
	Trolling			0.00	0.00	0.05	0.10	0.58	1.11	0.50	0.67		
	Alabama												
	Other fishing				0.00	0.04	0.01	0.00	0.04	0.00	0.00	0.00	0.00
	Trolling				0.00	0.04	0.75	0.51	1.21	0.26	0.23	0.00	0.00
	Mississippi												
	Other fishing				0.00	0.00	0.05	0.00	0.06	0.13	0.00	0.00	
	Trolling				0.00	0.21	0.45	0.62	0.50	0.00	0.17	0.27	
	Louisiana												
	Other fishing	0.32	0.00	0.01	0.00	0.00	0.09	0.64	0.32	0.28	0.65	1.39	0.16
	Trolling	2.24			0.00	0.25	0.42	0.79	1.45	1.66	1.75		
	N Texas												
	Other fishing				0.00	0.10		0.99	0.73	0.06	0.00	0.00	
	Trolling				0.03	0.15	1.04	2.49	1.33	0.28			
	S Texas												
	Other fishing				0.00	0.00	0.03	0.36	0.49	0.00	0.00		
	Trolling				0.29	0.90	0.29	1.45	1.40	1.39			
	US Caribbean												
	Other fishing												
	Trolling	0.11	0.09	0.15	0.16	0.14	0.05	0.13	0.06	0.02	0.07	0.11	0.20

Carolina in 1983; zone 2, south Texas in 1982; and zone 3, northwest Florida in 1984. Significant differences among any set of means within zone and year can be read from Table 9. For example, in zone 2 in 1983 northwest Florida, Louisiana, and north and south Texas had CPUE values significantly greater than all others except east Florida and Alabama.

Seasonality of CPUE

Patterns of CPUE among areas were evaluated separately for the south Atlantic and the Gulf coasts. Weekly estimates of trolling CPUE were plotted to analyze abundance of mackerel through time in relation to area. The data bases for other-fishing CPUE were too small and discontinuous to be of use in defining seasonal patterns except for Louisiana.

Seasonal patterns of CPUE along the south Atlantic coast were distinctly different among the areas compared. Along the North and South Carolina coasts, king mackerel were more abundant in the spring and fall than during the summer months (Fig. 2-5). In Georgia and northeast Florida, the fish were most abundant from May to September with one exception—in northeast Florida in 1983 a high CPUE value occurred in November (Fig. 3). Seasonal trends in CPUE in east and southeast Florida varied among years; in northeast Florida highest values occurred in May (1983), July (1984), and May (1985); in east Florida highest values occurred in November (1983), January (1984), and April (1985). In south Florida, the highest CPUE values occurred in the winter months.

A temperature-dependent migration pattern (north in the warm months and south in the cold months) was not indicated by the CPUE data. In the spring, king mackerel became abundant in the Carolinas at the same time, or earlier, than in Georgia and northeast Florida. The fish became abundant in the Carolinas in the fall after declines had occurred in Georgia and northeast Florida. Fish were also abundant in east, southeast, and south Florida during the late fall and winter.

In the Gulf of Mexico, it appeared that in the spring and early summer king mackerel simultaneously migrated northward along the east and west Gulf of Mexico coasts (Fig. 6-8). In 1983 through 1985, data were available from west and northwest Florida, Alabama,

Table 7.—Comparisons among fishing zones of yearly CPUE by area for king mackerel caught by trolling (CPUE values are arithmetic means).

	1982				1983				1984				1985			
	Zone				Zone				Zone				Zone			
Area	1	2	3	Range test[1]	1	2	3	Range test[1]	1	2	3	Range test[1]	1	2	3	Range test[1]
NC	0.00	0.00	0.44	1 2 3	1.74	0.34	0.64	2 3 1	0.00	0.97	1.25	1 3 2	0.00	2.24	1.26	1 3 2
SC						0.39	1.59						0.80	1.49	1.02	1 3 2
GA						0.28	1.06						0.00	1.01	1.43	1 2 3
NEFL					0.19	0.23	0.56	1 2 3					0.00	0.27	0.80	1 2 3
EFL					0.00	0.47	1.77	1 2 3	0.00	0.53	0.44	1 3 2		0.00	0.65	
SEFL					0.14	0.28	0.37	1 2 3		0.17	0.10			0.50	0.18	
SFL		0.32	0.09		0.03	0.20	0.08	1 3 2		0.17	0.17			0.38	0.31	
SWFL																
WFL					0.00	0.37	1.21	1 2 3	0.06	0.36	0.11	1 3 2		0.40	0.13	
NWFL	0.00	0.76	2.33	1 2 3	0.02	0.91	2.36	1 2 3	0.37	0.50	1.51	1 2 3	0.27	0.95	0.66	1 3 2
AL					0.00	0.52	0.10	1 3 2					0.00	0.85	0.00	1 3 2
MS						0.16	0.00						0.00	0.37	0.15	1 3 2
LA	0.00	0.00	0.13	1 2 3	0.00	1.46	0.68	1 3 2		1.51	0.67		0.00	0.79	0.75	3 2 1
NTX						1.19	2.49							1.43	1.84	
STX	0.00	1.15	1.70	1 2 3	0.00	0.87	0.57	1 3 2		0.65	0.21		0.31	1.43	1.01	1 3 2

[1]Any two zones not underscored by the same line have significantly different means.

Table 8.—Statistical comparisons among areas of Log (CPUE + 1) of king mackerel (analysis of variance and multiple range test). Any two logarithmic means not underscored by the same line are significantly different.

1982					
Log (CPUE + 1)	SFL 0.03	LA 0.04	NC 0.05	NWFL 0.14	STX 0.31
CPUE	0.11	0.13	0.40	0.72	1.30

1983																
Log (CPUE + 1)	SWFL 0.00	CARIB 0.01	SFL 0.03	MS 0.04	SEFL 0.10	WFL 0.10	NEFL 0.12	AL 0.13	NC 0.13	SC 0.13	GA 0.17	STX 0.18	LA 0.19	NWFL 0.23	EFL 0.31	NTX 0.37
CPUE	0.01	0.04	0.10	0.15	0.34	0.40	0.38	0.48	0.71	0.65	0.58	0.70	0.90	1.22	1.48	2.14

1984										
Log (CPUE + 1)	SWFL 0.00	SEFL 0.03	CARIB 0.04	SFL 0.05	STX 0.07	WFL 0.08	EFL 0.14	NC 0.16	NWFL 0.16	LA 0.21
CPUE	0.00	0.11	0.11	0.19	0.26	0.36	0.51	1.16	0.76	0.90

1985																
Log (CPUE + 1)	SWFL 0.00	CARIB 0.04	SEFL 0.06	SFL 0.07	WFL 0.09	MS 0.10	AL 0.12	NWFL 0.14	NEFL 0.14	EFL 0.17	NC 0.19	LA 0.23	GA 0.24	STX 0.26	SC 0.28	NTX 0.30
CPUE	0.00	0.11	0.19	0.33	0.39	0.36	0.50	0.56	0.51	0.64	1.41	0.90	1.03	1.16	1.24	1.49

Mississippi, Louisiana, and north and south Texas to evaluate migratory trends. With one exception, the fish were first abundant in March-April in west Florida, in May or June in north and south Texas, in May, June, or July in northwest Florida, Alabama, and Mississippi, and in September in Louisiana. The exception was that in west Florida the fish were never abundant in the spring of 1983. CPUE data obtained by trolling in Louisiana support the idea that fish migrate up both sides of the Gulf of Mexico (Fig. 6-8), but those large fish caught by using live bait drifted near oil rigs ("other fishing") support the idea that part of the population of large fish remains in the area year-round and that the abundance of these fish is greatest during colder months (Fig. 9). King mackerel became abundant in south Texas earlier than in north Texas in the two years that comparative data were available (Fig. 6, 8).

Among Years

Highest CPUE for king mackerel occurred in 1983 or 1985 when all areas were considered. The mean CPUE data and results of the statistical comparisons among years are given in Table 10. Of the areas having significant among-year differences, CPUE was highest in 1985 in North Carolina, Louisiana, and the U.S. Caribbean, and in 1983 in east Florida. Further, for those areas having sufficient data for comparison but which did not show significant differences, log (CPUE + 1) was always highest in 1983 or 1985.

Table 9.—Comparison among areas of CPUE by year and zone for king mackerel caught while trolling.

Year	Zone	Mean CPUE by area																Area in order of increasing CPUE and results of range test[1]
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1982																		
	2	0.00						0.32			0.76			0.00		1.15		1 13 7 10 15
	3	0.44						0.09			2.33			0.13		1.70		7 13 1 15 10
1983																		
	1	1.74			0.19	0.00	0.14	0.03	0.00	0.00	0.02	0.00		0.00		0.00		5 8 9 11 13 15 10 7 6 4 1
	2	0.34	0.39	0.28	0.23	0.47	0.28	0.20	0.03	0.37	0.91	0.52	0.16	1.46	1.19	0.87		8 12 7 4 6 2 9 3 1 5 11 10 15 14 13
	3	0.64	1.59	1.06	0.56	1.77	0.37	0.08		1.21	2.36	0.10	0.00	0.68	2.49	0.57	0.04	12 16 7 11 6 1 15 13 9 4 3 2 5 10 14
1984																		
	1	0.00				0.00				0.06	0.37						0.00	1 5 16 9 10
	2	0.97				0.53	0.17	0.17	0.00	0.36	0.50			1.51		0.65		8 7 6 9 10 5 1 15 13
	3	1.25				0.44	0.10	0.17		0.11	1.51			0.67		0.21	0.11	6 9 16 7 15 5 1 13 10
1985																		
	1	0.00	0.80	0.00	0.00						0.27	0.00	0.00	0.00		0.31		1 3 4 11 12 13 10 15 2
	2	2.24	1.49	1.01	0.27	0.00	0.50	0.38	0.00	0.40	0.95	0.85	0.37	0.84	1.43	1.43	0.27	5 8 4 7 9 16 12 6 11 13 3 10 15 2 14 1
	3	1.26	1.02	1.43	0.80	0.65	0.18	0.31		0.13	0.66	0.00	0.15	0.76	1.84	1.01	0.11	11 9 16 12 6 7 1 10 5 13 4 15 2 14 3

[1]Any two areas not underscored by the same line have significantly different means.

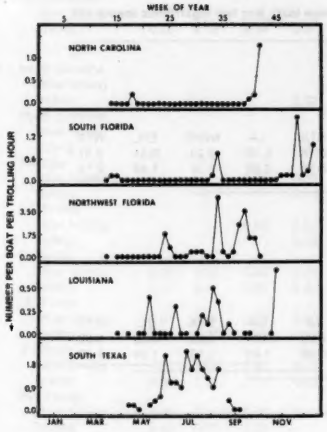

Figure 2.—CPUE by area for king mackerel caught by trolling on Atlantic and Gulf of Mexico coasts in 1982.

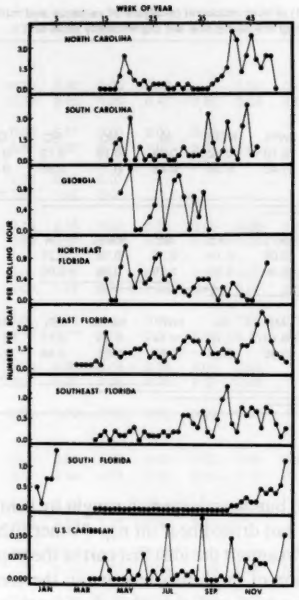

Figure 3.—CPUE by area for king mackerel caught by trolling on Atlantic and U.S. Caribbean coasts in 1983.

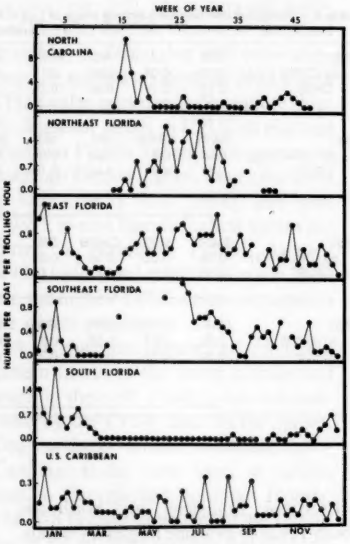

Figure 4.—CPUE by area for king mackerel caught by trolling on Atlantic and U.S. Caribbean coasts in 1984.

CPUE Data From Other Surveys

Sources of CPUE data for king mackerel from charter or private inboard recreational boats in the southeastern United States are provided in Table 2. The most extensive data bases are those provided by individual charterboat captains from Panama City and Destin, Fla., and from Orange Beach, Ala. All three of these captains fished for king mackerel as their target species. The remainder of the data bases defined in Table 2 cover areas no

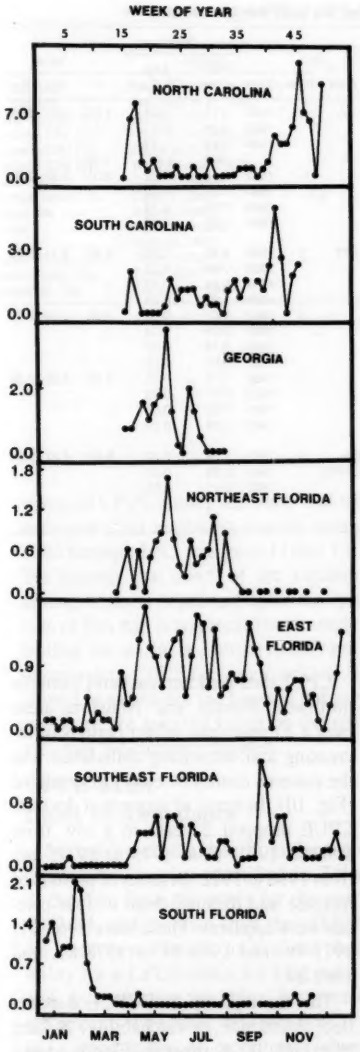

Figure 5.—CPUE by area for king mackerel caught by trolling on Atlanic coast in 1985.

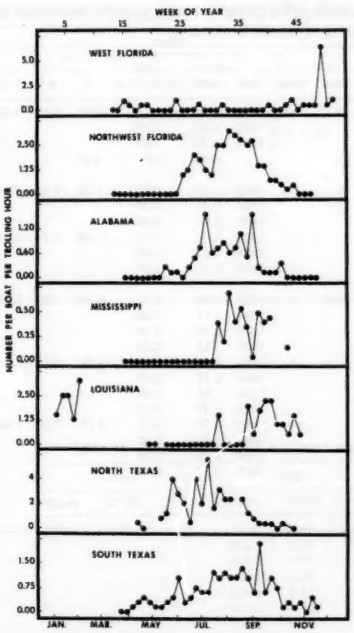

Figure 6.—CPUE by area for king mackerel caught by trolling on the U.S. Gulf coast in 1983.

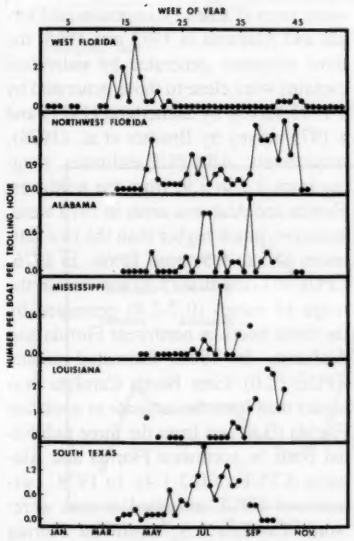

Figure 7.—CPUE by area for king mackerel caught by trolling on Gulf of Mexico coast in 1984.

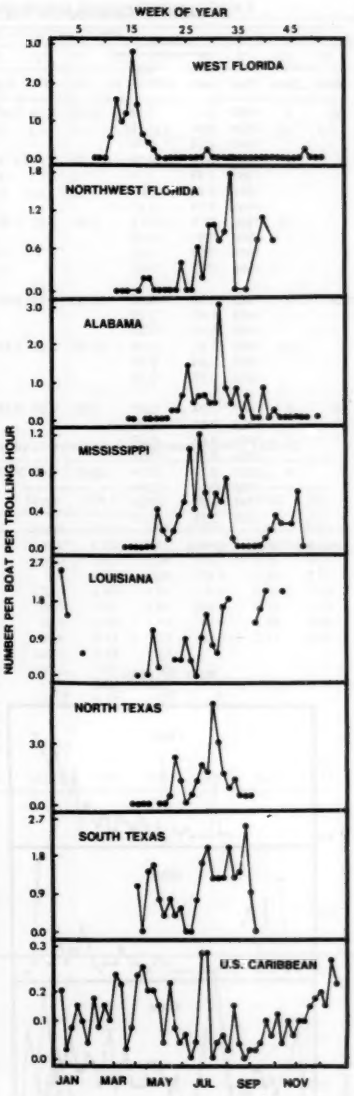

Figure 8.—CPUE by area for king mackerel caught by trolling on Gulf of Mexico and U.S. Caribbean coasts in 1985.

larger than a single state and time periods no longer than 2 years. Data from the NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) were not used because this survey did not, and was not designed to produce ample data for small geographic areas. Variability associated with these data is discussed by Nichols[1], who found the data too variable to pro-

[1]Nichols, S. 1985. A long-term catch per effort index for king mackerel. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., SEFC FAD Rep. ML1-85-18, 7 p.

Table 10.—Comparison for king mackerel of log (CPUE+1) among years for those areas, zones, and years with sufficient data.

Area	Zone	Year	Mean Arithmetic	Mean Log (CPUE+1)	F	d.f.	$F_{.10}$
NC	2	1983	0.41	0.14	6.84*	2,16	2.67
		1984	1.08	0.28			
		1985	2.33	0.50			
	3	1982	0.77	0.16	0.76	3,27	2.30
		1983	0.99	0.22			
		1984	2.79	0.35			
		1985	2.74	0.41			
	1-7	1982	0.75	0.14	1.30	3,27	2.30
		1983	0.91	0.23			
		1984	2.09	0.35			
		1985	2.57	0.42			
EF	3	1983	1.78	0.42	12.62*	2,24	2.54
		1984	0.41	0.16			
		1985	0.73	0.23			
	1-7	1983	1.41	0.36	10.75*	2,27	2.51
		1984	0.46	0.16			
		1985	0.72	0.23			
SF	2	1982	0.24	0.07	0.23	3,36	2.25
		1983	0.31	0.09			
		1984	0.22	0.07			
		1985	0.17	0.05			
	3	1982	0.10	0.04	0.70	3,40	2.23
		1983	0.12	0.04			
		1984	0.24	0.08			
		1985	0.38	0.10			
SF	1-7	1982	0.11	0.04	0.31	3,41	2.23
		1983	0.25	0.08			
		1984	0.23	0.08			
		1985	0.25	0.07			
WF	2	1983	0.51	0.15	1.06	2,24	2.54
		1984	0.31	0.09			
		1985	0.20	0.06			
	1-7	1983	0.57	0.16	0.99	2,24	2.54
		1984	0.31	0.09			
		1985	0.19	0.06			
NWF	2	1982	0.50	0.15	0.98	3,20	2.38
		1983	1.11	0.29			
		1984	0.53	0.16			
		1985	0.84	0.24			
	3	1982	2.10	0.45	2.29	3,11	2.66
		1983	2.17	0.48			
		1984	1.53	0.40			
		1985	0.37	0.16			
	1-7	1982	0.76	0.22	0.75	3,20	2.38
		1983	1.23	0.30			
		1984	0.79	0.24			
		1985	0.50	0.16			
LA	3	1982	0.11	0.04	1.03	3,21	2.36
		1983	0.38	0.17			
		1984	0.42	0.13			
		1985	0.48	0.22			
	1-7	1982	0.10	0.04	3.01*	3,23	2.34
		1983	0.57	0.20			
		1984	0.62	0.18			
		1985	1.05	0.32			
STX	2	1982	0.85	0.29	0.48	3,11	2.66
		1983	0.86	0.23			
		1984	0.88	0.27			
		1985	1.23	0.33			
	3	1982	1.01	0.25	2.08	3,18	2.42
		1983	0.58	0.19			
		1984	0.19	0.07			
		1985	0.83	0.25			
	1-7	1982	0.78	0.22	2.24	3,20	2.38
		1983	0.67	0.23			
		1984	0.22	0.08			
		1985	0.95	0.28			
US CARIB	3	1983	0.04	0.02	8.43*	2,27	2.51
		1984	0.09	0.04			
		1985	0.11	0.05			

*Significant at the $F_{.10}$ level.

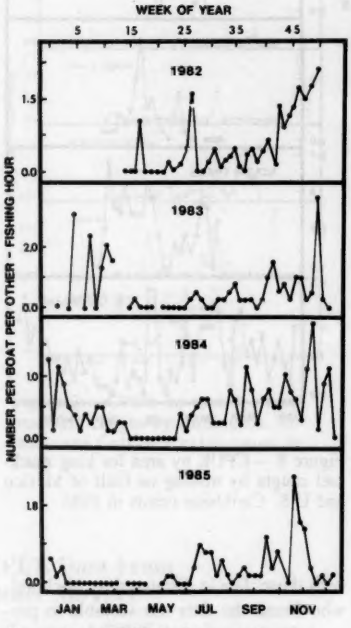

Figure 9.—CPUE for king mackerel caught by other fishing in Louisiana in 1982-85.

vide precise estimates for indices of abundance.

Annual estimates of CPUE for king mackerel within the southeastern United States varied greatly among areas in some years (Table 11). In northwest Florida and Alabama in 1973 and 1975, the three estimates generated by individual captains were close to those generated by a 1973 survey by Sutherland (1977) and a 1975 survey by Brusher et al. (1978), respectively. All CPUE estimates, ranging from 3.1 to 3.9, from the northwest Florida and Alabama areas in 1975 were, however, much higher than the two estimates (0.5 to 1.5) from Texas. In 1976, CPUE in Galveston (2.1) was within the range of values (0.7-2.4) generated by the three boats in northwest Florida and Alabama. In 1977, estimated annual CPUE (2.0) from North Carolina was higher than from the estimate in southeast Florida (0.6) and from the three individual boats in northwest Florida and Alabama (CPUE of 0.2-1.4). In 1978, estimates of CPUE in regard to area were: North Carolina 1.9, northwest Florida 1.3, and Grand Isle 1.1. In 1979 estimated annual CPUE for northwest Florida was 2.2 and for Texas was 0.6.

CPUE data for king mackerel from the northwest Florida and Alabama areas over a 20-year span reflect periods of increasing and decreasing abundance, but the patterns cannot be easily generalized (Fig. 10). In terms of sequential decline, CPUE dropped 2 years in a row from 1969 to 1971, from 1975 to 1977, and from 1980 to 1982. In terms of periods of increase and decline, three or four periods were apparent: These were 1965-71, 1971-78, and 1978-84 or 1978-82, and 1982-84.

The assumptions that CPUE data reflect abundance, or catchability, of king mackerel in northwest Florida seem valid. Although estimated annual mean CPUE by each of the three charterboats in northwest Florida and Alabama varied considerably, the directions of change from year to year were always the same (Fig. 10). Also the estimates by the surveys of Sutherland (1977) and Brusher et al. (1978) were in close agreement with those of the 3 boats in 1973 and 1975. Further, the estimates of CPUE from Captain Finnegan in 1983 and 1984 showed similar trends to those estimated from 15 boats in 1983 and 10 boats in 1984. However, the range of the esti-

Table 11.—Annual estimates of CPUE of king mackerel caught in the southeastern United States, 1965-85 from literature sources in Table 2.

Area	Literature source or boat captain	Mean number fish caught per boat fishing hour by year																		
		65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
N. Carolina	Manooch and Laws, 1979													2.0							
N. Carolina	Manooch et al., 1981														1.9						
Dade County, Fla.	Gentle, 1977													0.6							
Panama City, Fla.	Capt. J. Finnegan, Jr.						4.1	3.6		2.8	2.0	3.8	2.4	1.4	1.3	2.2	4.9	1.0	0.7	2.1	0.7
Panama City, Fla.	Sutherland, 1977									3.0											
Panama City, Fla.	Brusher et al., 1978											3.9									
Destin, Fla.	Capt. A. Hilpert									2.5	1.4	3.1	1.7	0.7							
Orange Beach, Ala.	Capt. T. Clark	0.6	1.9	1.5	1.6	1.6	1.1	0.8	1.1	2.8	2.0	3.5	0.7	0.2							
Grand Isle, La.	Fischer, 1980														1.1						
Texas	McEachron and Matlock, 1983															0.6					
Upper Padre, Tex.	Trent, 1976											1.5									
Lower Padre, Tex.	Trent, 1976											0.5									
Galveston, Tex.	Trent et al., 1977												2.1								

mates of CPUE among the boats that we surveyed from northwest Florida during 1983 through 1985 was great (Table 12). We suspect that much of the variation among boats is dependent upon the species of fish that is targeted. For example, trolling for marlin or sailfish usually produces a zero CPUE for king mackerel. It should be noted that the boats in our survey were not selected based on the species that the captains targeted.

CPUE as an Index to Abundance

Nichols[1] used the data from the three charterboat captains identified in Table 2, the data from this study for the years 1983-84, and the data from the MRFSS for northwest Florida, to evaluate their utility for a CPUE index for king mackerel. In evaluating the index, he pointed out reasons why these data sets may not be a good index of recruitment abundance in the Gulf of Mexico. One of the foremost reasons was that the data are obtained from only a small part of the range of the stock.

Data were made available in this study to look at the relations between CPUE in northwest Florida and in other areas of the southeastern United States for a 4-year period. These data coupled with analyses of length and age composition data can be used to evaluate the utility of predicting age-class strength. These analyses are not, however, presently available.

Table 12.—Mean annual CPUE and hours trolled by charterboats in northwest Florida, 1982-85.

1982			1983			1984			1985		
Hours	CPUE	S.D.	Hours	CPUE	S.D.	Hours	CPUE	S.D.	Hours	CPUE	S.D.
576.5	0.72	1.70[1]	518.0	2.09	3.34[1]	208.0	0.74	1.62[1]	128.0	0.21	0.35
			205.5	3.22	4.29	36.0	0.29	0.71	55.5	1.53	1.33
			113.0	0.73	1.45	118.0	0.61	1.18	175.5	0.39	0.71
			76.0	0.32	1.10	8.0	0.00	0.00	118.0	0.56	0.75
			423.0	1.43	1.87	172.5	1.30	1.72	115.0	0.55	1.20
			315.0	0.99	1.18	80.0	0.09	0.24	259.0	0.13	0.28
			315.0	1.11	1.13	56.0	0.43	1.10	42.5	2.46	2.99
			255.0	1.20	1.78	60.5	0.44	0.86	52.5	0.27	0.89
			354.5	0.92	1.63	260.5	0.76	1.22			
			14.0	2.29	3.23	269.5	1.02	1.80			
			160.0	1.01	1.01	12.0	0.00	0.00			
			19.0	0.00	0.00	144.0	0.17	0.34			
			150.0	1.00	1.72						
			129.0	0.03	0.09						
			65.5	1.11	2.19						
576.5[2]	0.72[3]	1.70[4]	3,112.5	1.34	2.16	1,425.0	0.71	1.40	946	0.49	1.11

[1]Data from Capt. Joe Finnegan, Jr.
[2]Total.
[3]Weighted mean.
[4]Annual S.D.

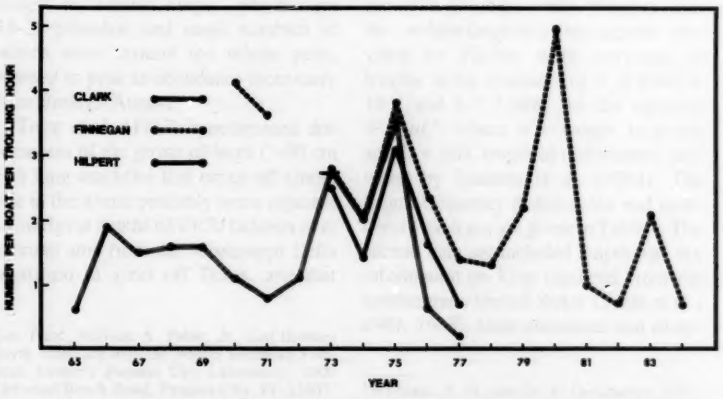

Figure 10.—CPUE by individual charterboat captain in northwest Florida and Alabama, 1965-84.

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Variations in Size and Sex Ratio of King Mackerel, *Scomberomorus cavalla*, off Louisiana, 1977-85

LEE TRENT, WILLIAM A. FABLE, Jr., SANDRA J. RUSSELL, GILBERT W. BANE, and BARBARA JAYNE PALKO

ABSTRACT—Data from over 27,000 king mackerel, Scomberomorus cavalla, *collected from Grand Isle, Louisiana, during 1977-85 were analyzed to evaluate temporal variations in size and sex compositions. The fish were caught by recreational and commercial hook-and-line fishermen.*

Groups of king mackerel from Louisiana were composed of a greater portion of large fish than were populations from other areas in the southeastern United States with the possible exception of South Carolina and Georgia. Large (>120 cm fork length) king mackerel were caught off Louisiana throughout the year. For both males and females, catches were composed of the smallest fish in April through October and the largest fish between November and March. Females dominated catches in most months and comprised a greater portion of the recreational than the commercial landings. Female percentage was usually lower in the warmer than in the colder months. In general, female percentage increased with an increase in fish size.

Introduction

A commercial hook-and-line fishery for king mackerel *Scomberomorus cavalla*, began off Louisiana during the winter of 1981-82. Three fishermen from Florida, along with their crews, began fishing for king mackerel off Grand Isle and landed over 12,000 pounds between 26 December and 15 January. The fishery expanded dramatically the following winter (November 1982-January 1983) when an estimated 30-50 boats landed over 1 million pounds of king mackerel at Grand Isle.

As the fishery expanded, interest in king mackerel off the Louisiana coast increased among fishermen, fishery managers, and fishery scientists. Information about king mackerel off Louisiana, however, was sparse. A newspaper article Marshall, 1983 in *The Times-Picayune*—based on interviews with charterboat captains, commercial fishermen, fish dealers, fishery managers, and fishery scientists—reported on the developing fishery and on many known or hypothesized aspects of king mackerel that occurred off Louisiana. Marshall provided the following: In the mid-1960's, charterboat skippers at Grand Isle became aware that large king mackerel, many in the 40-60 pound range, were available around the oil rigs 10-20 miles southeast of Grand Isle. According to fishermen that Marshall interviewed, the "winter kings" were fish between 35 and 60 pounds, showed up in November, reached peak numbers in January, and stayed on until mid-March; the "summer kings" or "Florida kings," which were 15-25 pounders and small numbers of which were around the whole year, seemed to peak in abundance from early June through August.

Trent et al. (1983) hypothesized that members of the group of large (>90 cm FL) king mackerel that occur off Grand Isle in the winter probably occur adjacent to oil rigs at depths of 10-50 fathoms over a broad area from the Mississippi Delta westward to areas off Texas, and that these fish do not participate in extensive north-south migrations as do smaller king mackerel. This hypothesis was mostly based on evaluation of length data of king mackerel from the southeastern United States (Trent et al., 1981) and on results of tagging studies in south Florida (Williams and Godcharles[1]) and areas of the northern Gulf (Sutherland and Fable, 1980).

This paper compares data on king mackerel length and sex distribution obtained in 1981-85 with those published previously.

Methods

Two data sets reporting lengths and sex ratios of king mackerel caught in Louisiana are published. One set includes weights (lengths were not reported) and sex ratios by season from 623 king mackerel weighed at Grand Isle from December 1977 through 30 November 1978 (Fischer, 1980). Weights from the weight-frequency histograms provided by Fischer were converted to lengths using constants ($a = 0.8464 \times 10^{-5}$ and $b = 2.9881$ for the equation $W = aL^b$, where W = weight in grams and L = fork length in millimeters) provided by Johnson et al. (1983). The length-frequency distributions and numbers of each sex are given in Table 1. The second data set included length and sex information on king mackerel from the southeastern United States (Trent et al., 1981, 1983). Data summaries and analy-

Lee Trent, William A. Fable, Jr., and Barbara Jayne Palko are with the NMFS Southeast Fisheries Center's Panama City Laboratory, 3500 Delwood Beach Road, Panama City, FL 32407. Sandra J. Russell and Gilbert W. Bane are with the Center for Wetlands Research, Louisiana State University, Baton Rouge, LA 70803.

[1]Williams, R. O., and M. F. Godcharles. 1983. Completion report. King mackerel tagging and stock assessment project 2-341-R. Florida Dep. Nat. Resour. Unpubl. Rep., 45 p.

Table 1.—Length-frequency distributions and numbers of each sex of king mackerel caught by recreational fishermen off Grand Isle, La., from December 1977 through November 1978 (from Fischer, 1980).

Midpoint of weight interval		Fork length	Number of fish			
lb	kg	(cm)	Dec.-Feb.	Mar.-May	June-Aug.	Sept.-Nov.
7.5	34	78		1	1	
12.5	57	90	8	2	24	15
17.5	79	101	17	8	57	40
22.5	102	109	14	14	63	17
27.5	125	117	10	20	33	5
32.5	147	124	14	31	26	1
37.5	170	130	10	32	26	2
42.5	193	135	7	39	7	4
47.5	216	141	8	25	10	3
52.5	238	145	5	12	1	2
57.5	261	150	1	3	1	
62.5	284	154	1	2		
67.5	306	158	1			
		Male	7	6	26	3
		Female	89	183	223	86

Table 2.—Numbers of king mackerel examined from the recreational fisheries in 1977-80 and from commercial fisheries in 1981-85 in Louisiana (M = male, F = female, U = sex unknown, and A = sexes combined).

Year and mo.	Recreational				Year and mo.	Commercial			
	M	F	U	A		M	F	U	A
1977					1981				
Feb.	1	24		25	Dec.	3	39		42
June	2	16	40	58					
July			32	32	1982				
Aug.			19	19	Dec.	39	235		274
Sept.	8	59		67					
Oct.	10	135	6	151	1983				
Dec.	3	38		41	Jan.	31	203	376	610
					Feb.	1	46	78	125
1978					Mar.			329	329
Jan.	3	36		39	Apr.	267	74		341
Feb.	8		8	16	Aug.	90	101	41	232
Mar.	4	64		68	Sept.	223	364	26	613
Apr.		3		3	Oct.	105	354	84	543
May	1	4		5	Nov.	24	24	20	68
June	7	60	1	68	Dec.			1,074	1,074
July	13	86	1	100					
Aug.	5	81		86	1984				
Sept.		24	1	25	Jan.	194	307	124	625
Oct.	4	75		79	Feb.	773	1,096	223	2,092
Nov.		34		34	Mar.	965	1,616	222	2,803
Dec.		7		7	Apr.	2		2	4
					May	56	6		62
1980					June	481	321	7	809
May	1			1	July	692	979	27	1,698
June	11	17	1	29	Aug.	81	249	2	332
July	5	30		35	Sept.	142	162	48	352
Aug.		35	4	39	Oct.	233	478	30	741
Sept.	3	43	1	47	Nov.	454	1,299	49	1,802
Oct.	8	50	2	60	Dec.	1,887	3,473	368	5,728
					1985				
					Jan.	124	370	32	526
					Feb.	1	9	0	10
					Mar.	100	119	4	223
					Apr.	0	1	0	1
					May	393	214	20	627
					June	420	264	33	717
					July	608	874	93	1,575
					Aug.	220	376	18	614
					Sept.	6	30	21	57
					Oct.	99	350	4	453
					Nov.	105	241	52	398
					Dec.	119	164	35	318

Table 3.—Number, mean fork length ($\bar{x}$ in centimeters), and sex ratio by month for king mackerel caught off Louisiana, 1977-85.

Gear, year, and mo.	Male		Female		Unknown		Sexes comb.		Percent female
	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	
Recreational hook and line									
1977									
Feb.	1	107	24	124	0		25	124	96.0
June	2	97	16	102	40	106	58	105	88.9
July					32	107	32	107	
Aug.					19	113	19	113	
Sept.	8	97	59	96	0		67	96	88.1
Oct.	10	89	135	103	6	98	151	102	93.1
Dec.	3	96	38	117	0		41	115	92.7
1978									
Jan.	3	92	36	116	0		39	114	92.3
Feb.	0		8	129	0		8	129	100.0
Mar.	4	124	64	130	0		68	129	94.1
Apr.	0		3	132	0		3	132	100.0
May	1	112	4	112	0		5	112	80.0
June	7	100	60	115	1	97	68	113	89.5
July	13	99	86	112	1	127	100	110	86.9
Aug.	5	93	81	117	0		86	115	94.2
Sept.	0		24	111	1	97	25	110	100.0
Oct.	4	94	75	105	0		79	105	94.9
Nov.	0		34	120	0		34	120	100.0
Dec.	0		7	125	0		7	125	100.0
1980									
May	1	72	0		0		1	72	0.0
June	11	34	17	46	1	37	29	41	60.7
July	5	72	30	97	0		35	95	85.7
Aug.	0		35	75	4	59	39	74	100.0
Sept.	3	85	43	82	1	89	47	83	93.5
Oct.	8	67	50	76	2	59	60	74	86.2
Commercial hook and line									
1981									
Dec.	3	91	39	98	0		42	98	92.9
1982									
Dec.	39	92	235	100	0		274	99	85.8
1983									
Jan.	31	89	203	104	376	102	610	102	86.7
Feb.	1	122	46	117	78	112	125	114	97.9
Mar.					329	103	329	103	
Apr.	267	74	74	75	0		341	74	21.7
Aug.	90	83	101	87	41	84	232	85	52.9
Sept.	223	80	364	77	26	73	613	78	62.0
Oct.	105	86	354	89	84	85	543	88	77.1
Nov.	24	79	24	82	20	88	68	83	50.0
Dec.					1,074	96	1,074	96	
1984									
Jan.	194	92	307	99	124	99	625	96	61.3
Feb.	773	90	1,096	99	223	94	2,092	95	58.6
Mar.	965	91	1,616	97	222	95	2,803	95	62.6
Apr.	2	77	0		2	107	4	92	0.0
May	56	86	6	111	0		62	88	9.7
June	481	81	321	85	7	87	809	83	40.0
July	692	87	979	92	27	95	1,698	90	58.6
Aug.	81	84	249	94	2	65	332	91	75.4
Sept.	142	83	162	86	48	84	352	85	53.3
Oct.	233	88	478	93	30	90	741	91	67.2
Nov.	454	89	1,299	96	49	95	1,802	94	74.1
Dec.	1,887	89	3,473	95	368	92	5,728	93	64.8
1985									
Jan.	124	91	370	99	32	102	526	97	74.9
Feb.	1	107	9	117	0		10	116	90.0
Mar.	100	85	119	85	4	96	223	85	54.3
Apr.	0		1	87	0		1	87	100.0
May	393	82	214	90	20	83	627	85	35.2
June	420	81	264	89	33	86	717	84	62.9
July	608	78	874	82	93	80	1,575	81	59.0
Aug.	220	78	376	87	18	86	614	83	63.1
Sept.	6	78	30	86	21	95	57	89	83.3
Oct.	99	88	350	95	4	80	453	93	77.9
Nov.	105	87	241	95	52	117	398	96	69.6
Dec.	119	87	164	93	35	88	318	90	56.9

Table 4.—Percentage composition of female king mackerel by type of gear, year, and size class. Ratios in parentheses were determined from samples <10 fish.

Fork length interval (cm)	Rec. hook and line			Comml. hook and line				
	1977	1978	1980	1981	1982	1983	1984	1985
30-49			48.3			(50.0)		(0.0)
50-69	(100.0)		95.6			60.2	29.3	73.1
70-89	85.4	80.0	90.5	(85.7)	64.3	47.4	52.3	48.3
90-109	90.2	86.5	76.5	93.3	88.0	75.7	70.2	70.0
110-129	98.1	97.3	90.0	(100.0)	100.0	97.2	97.4	91.9
130-149	100.0	98.9	100.0		(100.0)	100.0	100.0	97.9
150-169	(100.0)	(100.0)			(100.0)	(100.0)	(100.0)	
30-169	91.9	92.9	86.2	92.9	85.8	61.1	62.6	57.8

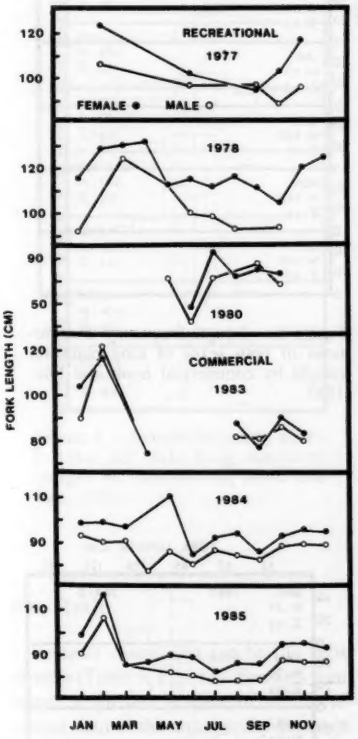

Figure 1.—Monthly mean fork lengths of king mackerel caught off Louisiana by sex, year, and type of fishing.

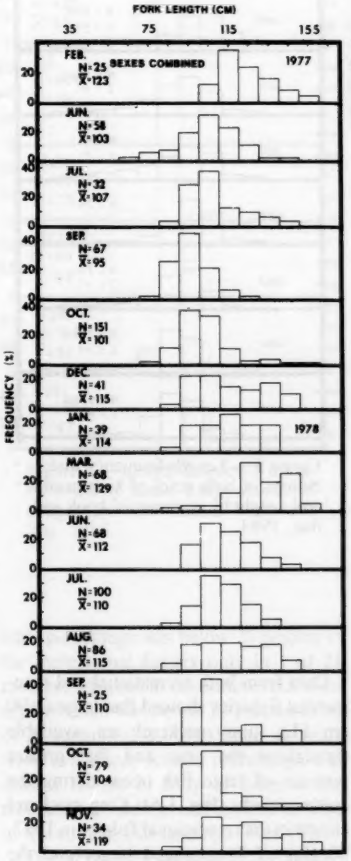

Figure 2.—Length-frequency distribution of both sexes of king mackerel caught by recreational hook and line, 1977-78.

ses that pertain to Louisiana from the published data are assembled with the newly acquired data and are reproduced in this report.

King mackerel were sampled from recreational landings during 1977-80 (Fischer, 1980; Trent et al., 1983) and from commercial landings during 1981-85 from Louisiana. The fish were caught by recreational fishermen using a wide assortment of baits and artificial lures while trolling and by drifting live sand seatrout, *Cynoscion arenarius*, Atlantic croaker, *Micropogonias undulatus*, or other species near oil rigs located in water depths from 12 to 45 m. The baits for drift fishing were large and usually ranged in weight from 0.2 to 0.7 kg. In the commercial hook-and-line fishery, lines with spoons, nylon filament jigs (often with strips of fish), and baits such as the cigar minnow, *Decapterus punctatus*, were trolled behind boats and retrieved manually or with hydraulic or electric reels (Harris, 1974; Marshall, 1983). Planers or weights were often used to fish the lures deep.

Length measurements were taken from both whole and gutted fish. Fork lengths were measured from the tip of the snout (mouth closed) to the fork of the tail to the nearest millimeter, centimeter, or 0.1 inch. All measurements were later converted to millimeters or centimeters. Data were summarized in relation to sex, capture gear, and month. Length data were grouped into 1, 2.5, and 10 cm intervals during preliminary analysis. In this report, length data are presented in 5 or 10 cm intervals.

The numbers of king mackerel that were measured and sexed are in Table 2; sex ratios by month and mean length by sex and month are in Table 3; and sex ratios by year and length interval are in Table 4. The third set of length measurements of king mackerel were taken from December 1981 through December 1985 from the newly developed commercial hook-and-line fishery out of Grand Isle and from biologists obtaining fish for tagging. These data have been summarized and are included in Tables 2-4.

Results

Size

King mackerel caught in Louisiana ranged in fork length from 30 to 155 cm; monthly mean fork lengths (sexes combined) ranged from 41 to 132 cm (Table 3). Mean lengths of females were greater than those for males in 40 of 45 months, and were the same for the two sexes in 2 months, when comparative data (lengths for each sex) were available (Fig. 1).

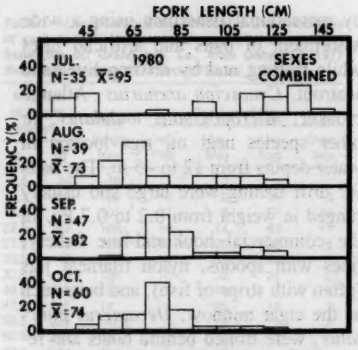

Figure 3.—Length-frequency distributions of both sexes of king mackerel caught by recreational hook and line, 1980.

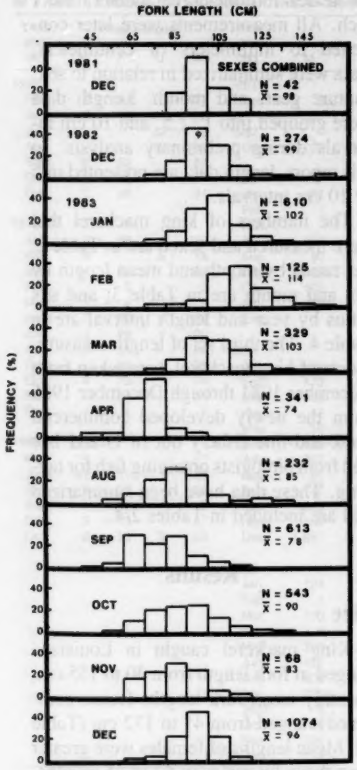
FORK LENGTH (CM)
45 65 85 105 125 145
1981 DEC SEXES COMBINED N = 42 X = 98
1982 DEC N = 274 X = 99
1983 JAN N = 610 X = 102
FEB N = 125 X = 114
MAR N = 329 X = 103
APR N = 341 X = 74
AUG N = 232 X = 85
SEP N = 613 X = 78
OCT N = 543 X = 90
NOV N = 68 X = 83
DEC N = 1074 X = 96
FREQUENCY (%)

Figure 4.—Length-frequency distributions of both sexes of king mackerel caught by commercial hook and line, 1981-83.

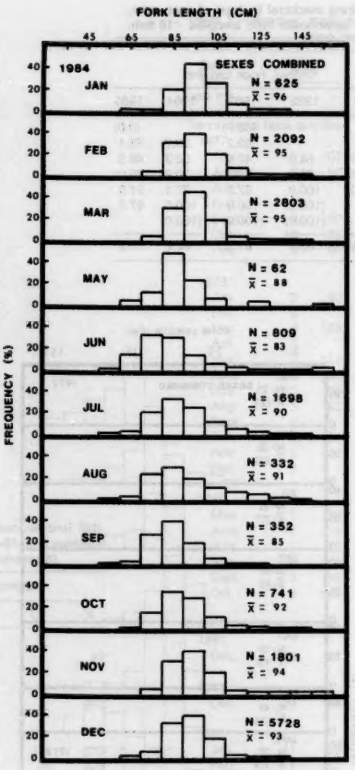
FORK LENGTH (CM)
45 65 85 105 125 145
1984 JAN SEXES COMBINED N = 625 X = 96
FEB N = 2092 X = 95
MAR N = 2803 X = 95
MAY N = 62 X = 88
JUN N = 809 X = 83
JUL N = 1698 X = 90
AUG N = 332 X = 91
SEP N = 352 X = 85
OCT N = 741 X = 92
NOV N = 1801 X = 94
DEC N = 5728 X = 93
FREQUENCY (%)

Figure 5.—Length-frequency distributions of both sexes of king mackerel caught by commercial hook and line, 1984.

Data from both recreational and commercial fisheries showed that large (>90 cm FL) king mackerel are available throughout the year and that greater portions of large fish occur during the colder months (Fig. 1-6). King mackerel caught in the recreational fishery in 1977-80 (Fig. 2-3) averaged larger and the catches were composed of more large fish than those caught in the commercial fishery in 1983-85 (Fig. 4-6).

In general, mean lengths of members of each sex were closely correlated through time (Fig. 1). For both females and males the catches were composed of the smallest fish during April through October of each year (Fig. 7-14).

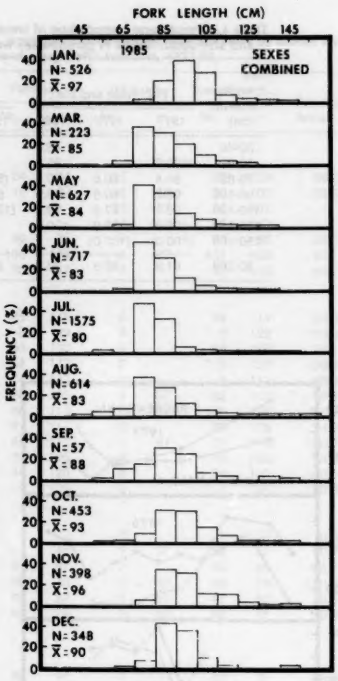

Figure 6.—Length-frequency distributions of both sexes of king mackerel caught by commercial hook and line, 1985.

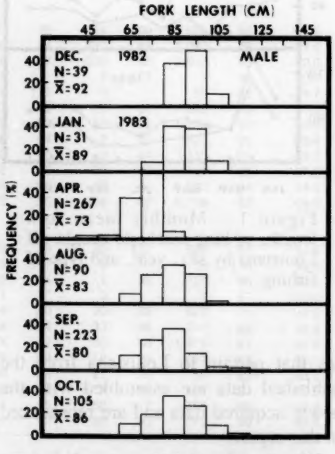

Figure 7.—Length-frequency distributions of male king mackerel caught by commercial hook and line, 1982-83.

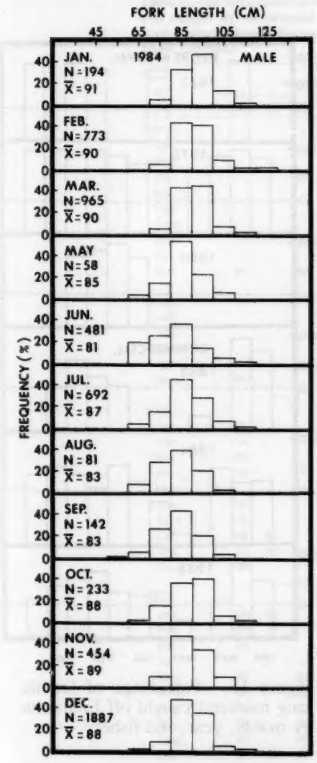

Figure 8.—Length-frequency distributions of male king mackerel caught by commercial hook and line, 1984.

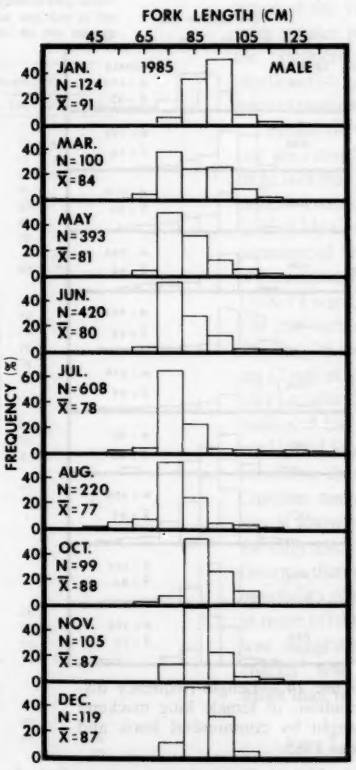

Figure 9.—Length-frequency distributions of male king mackerel caught by commercial hook and line, 1985.

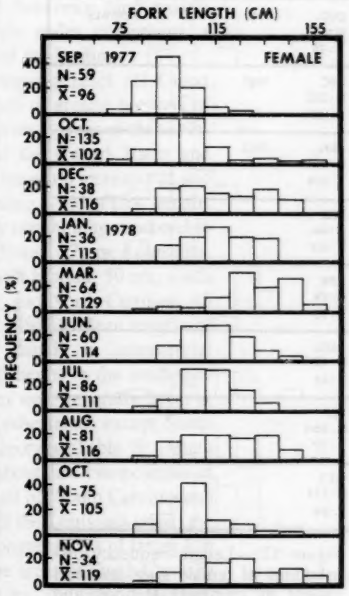

Figure 10.—Length-frequency distributions of female king mackerel caught by recreational hook and line, 1977-78.

Sex Ratio

Females dominated catches in most months (Table 3, Fig. 15). Females comprised a greater portion of the recreational than of the commercial landings. Annual sex ratios (female percentage) by gear type for those years with sample sizes of 100+ fish were: Recreational 1977, 91.9 percent; 1978, 92.9 percent; 1980, 86.2 percent. Commercial 1982, 85.8 percent; 1983, 61.1 percent; 1984, 62.6 percent; and 1985, 57.8 percent. Female percentage was below 70 percent in the recreational fishery only in 1 of 21 months, whereas in the commercial fishery the value was below 70 percent in 19 of 29 months (Fig. 15). When all years were evaluated, female percentage was always lowest in May or June in the recreational landings and in April or May in the commercial landings (Fig. 15).

The degree of dominance of female king mackerel varied in relation to size of fish and in relation to capture gear, year, or both (Table 4). For the recreational

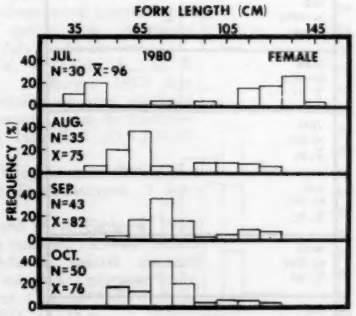

Figure 11.—Length-frequency distributions of female king mackerel caught by recreational hook and line, 1980.

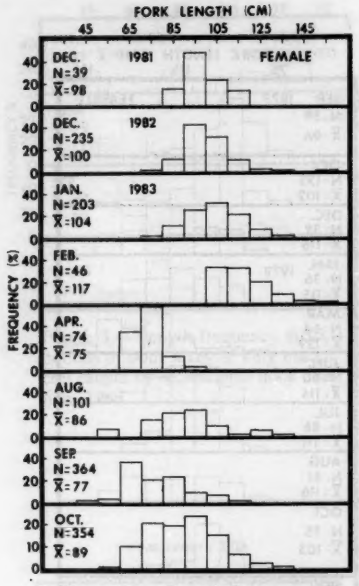

Figure 12.—Length-frequency distributions of female king mackerel caught by commercial hook and line, 1981-83.

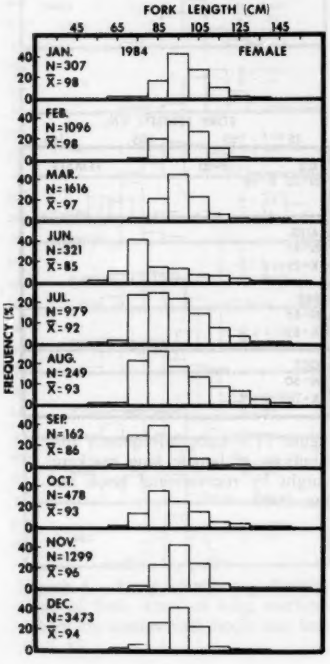

Figure 13.—Length-frequency distributions of female king mackerel caught by commercial hook and line, 1984.

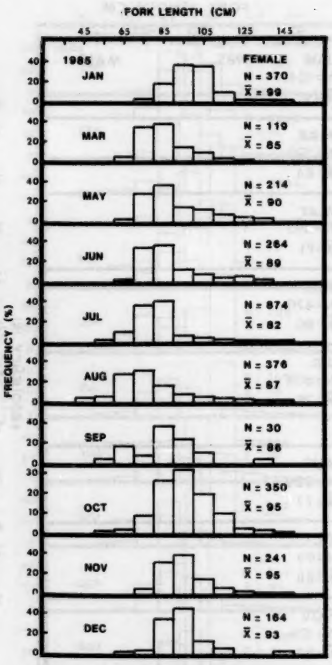
FORK LENGTH (CM)
45 65 85 105 125 145
FREQUENCY (%)
1985 JAN FEMALE N = 370 X̄ = 99
MAR N = 119 X̄ = 85
MAY N = 214 X̄ = 90
JUN N = 264 X̄ = 89
JUL N = 874 X̄ = 82
AUG N = 376 X̄ = 87
SEP N = 30 X̄ = 86
OCT N = 350 X̄ = 95
NOV N = 241 X̄ = 95
DEC N = 164 X̄ = 93

Figure 14.—Length-frequency distributions of female king mackerel caught by commercial hook and line, 1985.

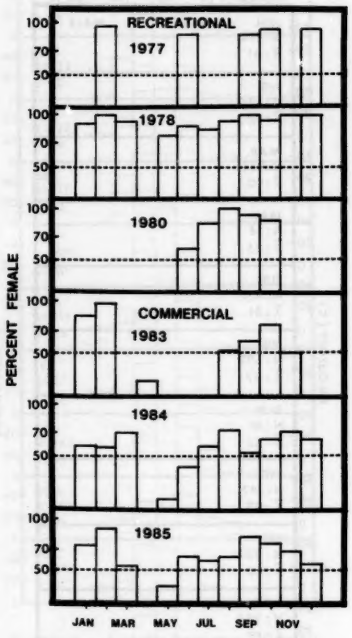

Figure 15.—Percentage of female king mackerel caught off Louisiana by month, year, and fishery.

fishery in the years 1977-80, female percentage increased with an increase in fish size in every case except for the 70-89 and 90-109 cm size classes in 1980. The same general trend of increasing female percentage with increasing fish size was reflected in the commercial data, but the female percentage was much lower in fish <90 cm in the commercial than in the recreational landings.

Discussion

Seasonal changes in size and sex ratio were not as apparent in the recreational landings as in the commercial landings. Recreational fishermen seek the largest fish and use techniques such as drifting live fish around oil rigs to increase their probability of catching the largest fish (Trend et al., 1983). Commercial fishermen are interested in large landings in pounds and dollars and their fishing strategy varies depending on fish availability

Table 5.—Monthly mean fork lengths of king mackerel caught by commercial hook and line in the southeastern United States, 1981-85 (for sample sizes ≥25 fish).

Year and mo.	Mean fork length (cm)						
	LA	NC	SC	GA	EFL[1]	SFL[2]	NWFL[3]
1981							
Jan.					73	81	
Feb.					71	73	
Mar.					69	71	
Apr.					75		
May					80		
June					84		
July					78		
Nov.						77	
Dec.	98				83	75	
1982							
Jan.					79		
Feb.					79		
Mar.					76		
Apr.					74		
Dec.	99				86		
1983							
Jan.	102				82		
Feb.	114				72		
Mar.	103				77		
Apr.	74						
May					91		
Aug.	85						62
Sept.	78						
Oct.	88	85					
Nov.	83	86					
Dec.	96						
1984							
Jan.	96	86			66		
Feb.	95	77			72		
Mar.	95				70		
Apr.				94	74		
May	88		94				
June	83		92	90			
July	90		91	87			
Aug.	91		92		82		
Sept.	85		86		87		73
Oct.	91	82	82				73
Nov.	94	84	88				
Dec.	93	89	88				
1985							
Jan.	97						
Mar.	85						
May	85						
June	84						
July	81						
Aug.	83						
Sept.	89						
Oct.	93						
Nov.	96						
Dec.	90						
Non-weighted mean	90.7	84.1	89.1	90.3	77.4	75.4	69.3

[1]East Florida from Holly Hill to Boca Raton.
[2]South Florida from Key Largo to Key West.
[3]Northwest Florida from Yankee Town to Alabama-Florida line.

and price paid per pound for each size of fish. In the king mackerel fishery off Grand Isle in 1983-85, the price paid per pound for fish under 10-15 pounds was often much more than that paid for fish above this size; occasionally a market did not exist for the large fish. During times of depressed prices for large fish, and times of the year when small fish comprise greater portions of the population, the commercial fishermen land mostly smaller fish with males comprising a greater portion of the landings.

Groups of king mackerel off Grand Isle are composed of greater portions of large fish than in most areas of the southeastern coast of the United States and Gulf of Mexico based on recreational and commercial landings. Mean fork lengths of recreationally caught king mackerel in 1978-79 were: Texas, 87 cm; Louisiana, 114 cm; northwest Florida, 59 cm; south Florida, 76 cm; and North Carolina, 85 cm (Trent et al., 1983). Mean lengths of king mackerel caught in commercial hook-and-line fisheries in the southeastern United States were generally larger in Louisiana than other areas except South Carolina and Georgia (Table 5). Much less is known about size composition of the king mackerel off South Carolina and Georgia than off the Louisiana coast; the possibility of congregations of larger fish in more offshore areas of South Carolina was suggested by Williams and Godcharles[1] who caught larger fish in offshore than in inshore areas.

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Movements of King Mackerel, *Scomberomorus cavalla*, Tagged in Southeast Louisiana, 1983-85

WILLIAM A. FABLE, Jr., LEE TRENT, GILBERT W. BANE, and STEVEN W. ELLSWORTH

ABSTRACT—King mackerel, Scomberomorus cavalla *(1,968) caught by hook and line off Grand Isle, Louisiana, were tagged with internal anchor tags and released between 1983 and 1985. Fifty-five tags were recovered, providing an overall return rate of 2.8 percent. King mackerel tagged in winter were returned in every month of the year, but always from the Grand Isle area or westward as far as Veracruz, Mexico. All but one summer-tagged fish were returned in winter months from the Grand Isle area, Key West, Florida, or from Mexico. Winter-tagged fish were mostly large and mostly remained in the northwest Gulf. Summer-tagged fish tended to stay in the northwest Gulf if they were large, or migrated to south Florida or Mexico if they were small. The data indicate that the northwest Gulf maintains resident large king mackerel year round, and that these fish mix with smaller migrants from south Florida and Mexico to some degree in warmer months.*

Introduction

The king mackerel, *Scomberomorus cavalla*, is an important sport and commercial species on the south Atlantic and Gulf of Mexico coasts of the United States and Mexico. U.S. commercial fishermen landed 2.4 million kg (5.3 million pounds) of king mackerel worth $5.4 million in 1985 and U.S. recreational fishermen landed 5.3 million kg (11.6 million pounds) in 1985 (USDOC, 1986a, b).

Because of its value and popularity, the king mackerel has been the subject of intensive research by Federal and state agencies for years. Mark-recapture studies to determine migration and movement have been an important part of this research. Results of previous mark-recapture studies were reported by Sutherland and Fable (1980) and by Williams and Godcharles.[1]

Large king mackerel have been known to occur throughout the year in the Gulf of Mexico off Louisiana, but initial efforts at tagging these fish were unsuccessful (Sutherland and Fable, 1980). The development of a commercial handline fishery off Grand Isle, La., in the winter of 1982-83, however, made it possible to acquire large numbers of these fish for tagging and increased the need for fishery managers to know the stock identity of these fish. It was known that the abundance of large king mackerel increased in winter, and that smaller fish were caught during late summer months (Trent et al., 1983). We thought this seasonal heterogeneity in fish size indicated that different groups of king mackerel occurred off Louisiana at different times of the year.

This report details the results of a cooperative mark-recapture study of king mackerel conducted off Louisiana between 1983 and 1985 by the National Marine Fisheries Service (NMFS) and the Coastal Fisheries Institute of Louisiana State University. The objectives of this study were to determine migratory patterns of king mackerel of various sizes tagged in Louisiana in winter and summer.

William A. Fable, Jr., and Lee Trent are with the NMFS Southeast Fisheries Center's Panama City Laboratory, 3500 Delwood Beach Road, Panama City, FL 32407. Gilbert W. Bane is with the Center for Wetlands Research, Louisiana State University, Baton Rouge, LA 70803, and Steven W. Ellsworth is with the Tennessee Wildlife Resource Agency, Crossville, TN 38555.

[1]Williams, Roy O., and Mark F. Godcharles. 1984. Completion report, king mackerel tagging and stock assessment. Project 2-341-R. Fla. Dep. Nat. Resour. Unpubl. rep., 45 p.

Materials and Methods

The Louisiana commercial fishery is centered in Grand Isle, and all tagging of winter fish was done within 48 km (30 miles) of this location. In the summer months the fishermen go farther west, sometimes all the way to Texas, but all tagged fish were released within 96 km (60 miles) of Grand Isle (Fig. 1).

All king mackerel tagged in this study were caught by handlines either on commercial or government-owned boats. This method of collecting fish for tagging was proven effective by Williams and Godcharles.[1] Fish are taken in a vigorous condition with slight opportunity to exhaust themselves such as when caught on rod and reel. Two methods were used to immobilize the fish once they were lifted onto the vessel. Early in the study, fish were held down on deck or bent into a corner of the cockpit to immobilize them. Later, as more tagging was done on commercial vessels, fish were unhooked over an unhooking bar and were then held in a V-shaped, foam-padded tagging trough. As long as the foam padding and the trough were wet, mucous and scale loss appeared minimal.

We used internal anchor tags which have been proven effective for king mackerel by Williams and Godcharles[1]

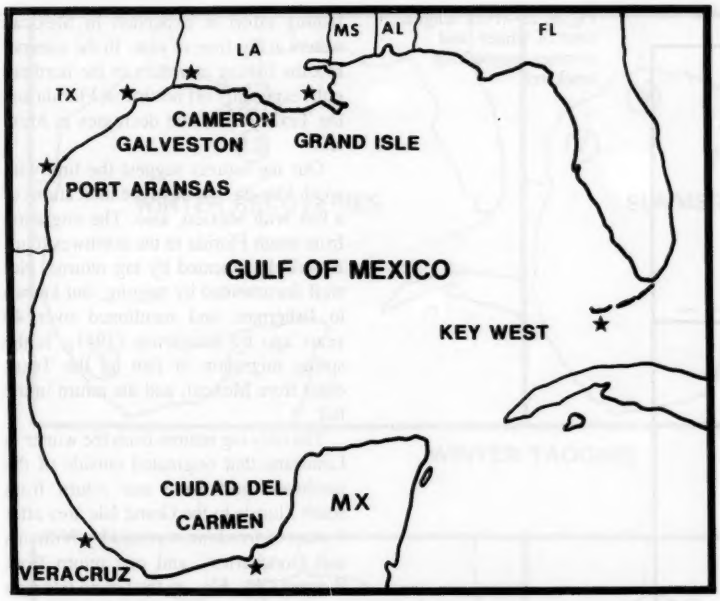

Figure 1.—Study area.

who reported tags returned from fish after more than 6 years of freedom. Our tags were international orange with a retainer disk 32 mm (1 1/4 inches) long and 8 mm 5/16 inch) wide with a 89 mm (3 1/2-inch) streamer. Each tag bore a number, and a legend indicating a return address and that a reward was offered for the tag return. We paid a $10 reward for each returned tag, and posters advertising this were distributed from Texas to south Florida by NMFS port agents and samplers, and along the Mexican Gulf coast by LSU researchers. Tags were applied in the abdominal area of the fish either by making a scalpel cut and slipping the disk end into the abdomen, or by using a special applicator, designed by the second author, which simplified tagging.

The fork length (mm) of each tagged fish was recorded before release for two reasons: It could provide information on growth if an accurate measurement was obtained at recovery, and it was used to compute the weight of the catch (after converting length to weight with published length-weight equations) so that the commercial fishermen could be paid for their mackerel catch.

Results and Discussion

Between January 1983 and November 1985, 1,968 king mackerel were tagged. Sixteen hundred and two of these were tagged in the colder six months (November through April) with the majority (1,478) tagged in December and January. During the warmer 6 months (May through October), 366 king mackerel were tagged, 300 of which were tagged in June. The fish tagged during colder months were mostly over 85 cm FL and the fish tagged during warmer months were mostly under 85 cm FL (Fig. 2).

Fifty-five tags have been recovered (Table 1), providing an overall return rate of 2.8 percent. Of the 55 recovered tags, 39 were from fish tagged from November through January, and 16 were from fish tagged from June through September. The returns from November-through-January tagged fish occurred in every month of the year, but were always from the Grand Isle area and westward as far as Veracruz, Mex. (Fig. 3). However, all but one summer-tagged fish were returned in winter months (December through February), from the Grand Isle

Table 1.—Information on tag returns for king mackerel tagged in Louisiana, 1983-85 (FL = fork length in mm).

Season and area of recovery	Date tagged	FL at tagging	Date recovered	Days out
Returns from winter tagging Nov.-April				
Grand Isle	1-14-83	1,100	2-2-83	19
	12-10-83	930	11-25-84	351
	12-13-83	975	12-8-84	361
	12-10-83	1,022	12-16-84	372
	11-25-84	895	12-20-84	25
	12-10-83	1,000	1-20-85	407
	11-25-84	950	4-5-85	131
	1-6-85	950	11-28-85	326
	12-10-83	990	12-9-85	730
	12-15-83	989	1-4-86	751
	1-6-85	1,015	1-11-86	370
	12-10-83	968	4-26-86	868
	12-13-83	1,020	1-28-86	777
Veracruz	12-13-83	1,100	3-13-84	91
May-Oct.				
Grand Isle	1-7-83	998	7-10-83	184
	1-7-83	1,025	8-7-83	212
	1-7-83	1,000	10-10-84	642
	12-31-84	900	5-10-85	130
	11-25-84	1,090	6-25-85	212
	1-6-85	835	7-11-85	186
	12-9-83	945	7-19-85	588
	12-9-83	850	10-14-85	675
	12-13-83	966	10-24-85	681
Cameron	12-13-83	917	5-25-85	529
	12-10-83	985	6-24-86	928
Galveston	12-10-83	950	7-18-84	221
	12-10-83	982	7-21-84	224
	12-13-83	900	8-19-84	250
	12-10-83	925	7-20-85	588
	12-13-83	960	7-20-85	585
	12-13-83	965	7-21-85	586
	12-10-83	885	8-7-85	606
Port Aransas	1-9-83	1,010	6-17-83	159
	1-14-83	980	8-7-83	205
	1-6-83	1,007	8-22-83	228
	1-7-83	1,015	8-20-84	591
	12-15-83	990	9-1-84	261
	12-10-83	830	5-25-85	532
	12-10-83	902	8-6-85	605
Returns from summer tagging Nov.-April				
Grand Isle	6-25-85	700	12-1-85	159
	6-24-85	890	12-4-85	163
	6-24-85	920	12-17-85	176
	6-25-85	820	1-28-86	217
	8-9-85	1,170	1-28-86	172
	6-26-85	1,140	1-29-86	217
	6-24-85	830	2-4-86	225
Key West	9-26-85	920	1-15-86	111
	6-24-85	800	2-3-86	224
	6-25-85	795	2-9-86	229
	6-26-85	715	2-9-86	228
	6-26-85	755	2-9-86	228
	6-25-85	600	2-16-86	236
	6-26-85	710	2-16-86	235
Ciudad del Carmen	6-25-85	725	2-15-86	235
May-Oct. Galveston	6-25-85	880	6-15-86	358

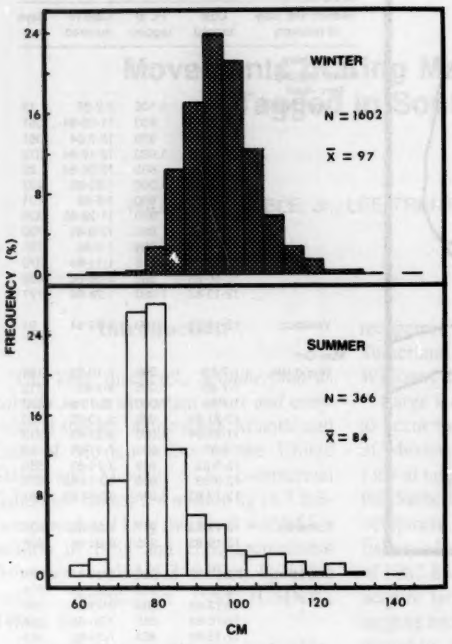

Figure 2.—Fork lengths (cm) of winter- and summer-tagged king mackerel.

area, from Key West, Florida or from Mexico (Fig. 3). The only summer-tagged fish recovered in the summer was from Texas.

Our returns from summer tagging off Grand Isle indicate that some mackerel from this area winter in south Florida and Mexico, but some apparently remain in the northern Gulf through the winter months. We know from tagging in the 1970's by Sutherland and Fable (1980) and Williams and Godcharles[1] that some (6) king mackerel tagged off Texas in the summer were recovered off south Florida in winter, and vice versa (43). Our data seem to indicate that, for the most part, the smaller fish migrate to south Florida or Mexico, and the larger fish remain behind. From our sixteen returns from summer-tagged fish, the fork lengths at tagging for fish (8) recovered at Key West or Mexico ranged from 600 to 920 mm and averaged 752 mm, while the lengths for fish (8) recovered in Louisiana or Texas ranged from 700 to 1,170 mm and averaged 919 mm.

King mackerel from the Louisiana winter fishery are larger on the average than those from any other area of the southeast U.S. (Trent et al., 1983). The mean fork length at tagging for recovered winter tagged fish was 967 mm. The fact that smaller fish presumably migrate through this area, yet larger fish remain, suggests that the northwest Gulf of Mexico may acquire resident larger fish that previously migrated through the region.

Our data suggests that king mackerel found off Grand Isle in the winter either remain in the northwestern gulf, or move southwestward into Mexico. We feel that the distribution of these fish along the Texas-Louisiana coast in summer (Fig. 3) also occurs to some extent in winter, but fishing effort in winter is very limited except off Grand Isle.

Interpretation of tag return information is difficult when fishing effort varies by season and location. In winter in the Gulf of Mexico, the heaviest fishing pressure on king mackerel occurs in the Key West area, and also off Grand Isle. Moderate fishing effort is expended in Mexican waters at this time of year. In the summer months fishing increases in the northern gulf, especially off northwest Florida and the Texas coast, and decreases in Mexico.

Our tag returns suggest the link with south Florida, but there are indications of a link with Mexico, also. The migration from south Florida to the northwest Gulf is well documented by tag returns. Not well documented by tagging, but known to fishermen and mentioned over 40 years ago by Baughman (1941), is the spring migration of fish up the Texas coast from Mexcio, and the return in the fall.

The only tag returns from the winter in Louisiana that originated outside of the northwest gulf were one return from south Florida to the Grand Isle area after 4 years of freedom, reported by Williams and Godcharles[1], and one return from Panama City, Fla., to the Grand Isle area from tagging done by the first two authors in 1983. Panama City king mackerel have well documented migrations to south Florida (Sutherland and Fable, 1980) and presumably this fish was from that migratory group. We have no tagging evidence for recruitment into the Louisiana winter fishery from Mexico, except what can be implied from two king mackerel that were tagged off Veracruz and recovered off Texas, (Williams and Godcharles[1] and data on file at the NMFS Panama City Laboratory).

Conclusions

King mackerel tagged off Grand Isle, La., in the winter months were mostly large fish (over about 850 mm FL), and they mostly remained in the northwest Gulf. King mackerel tagged off Grand Isle in the summer months tended to stay in the northwest Gulf if they were larger than about 800 mm FL, or migrated to south Florida or Mexico if they were smaller than that.

We feel the data indicate that the northwest Gulf maintains a resident population of larger king mackerel year round, which may move into Mexico to some extent, and that this group mixes to some degree in the warmer months with

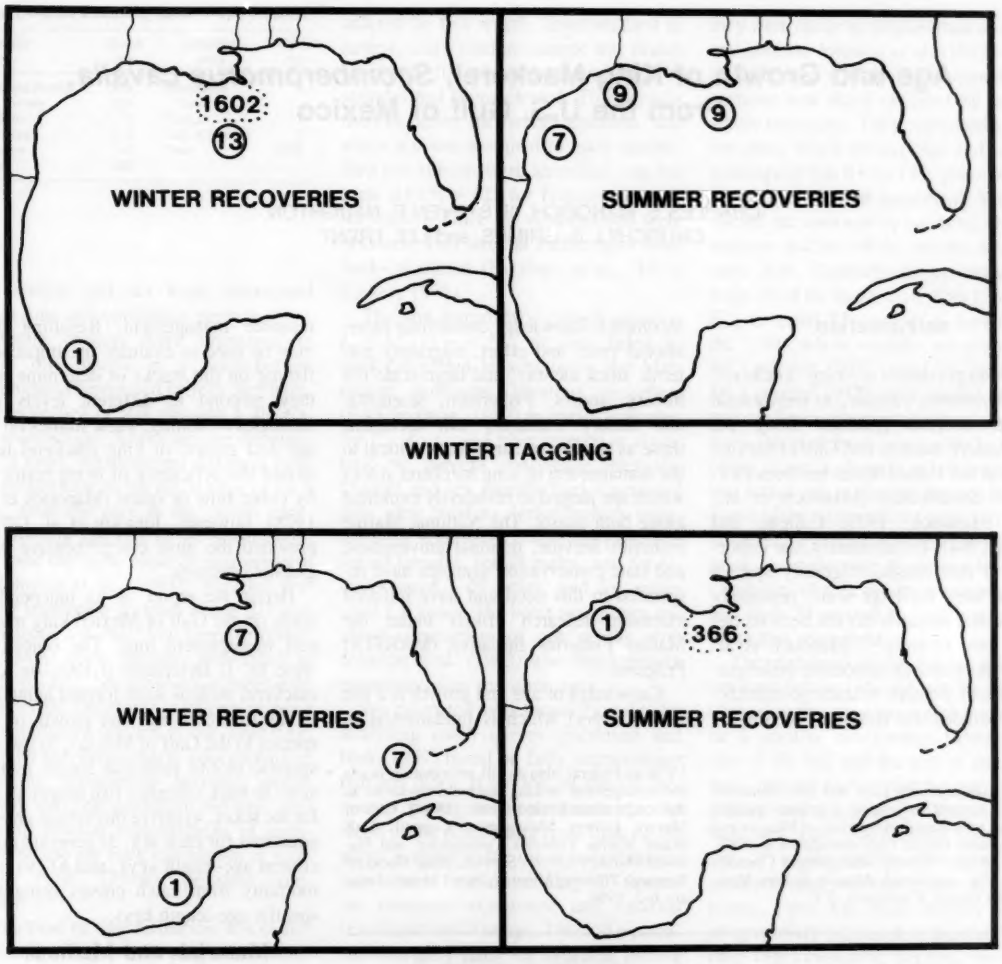

Figure 3.—Numbers of tagged king mackerel (in dots) and recovered king mackerel (in circles) by time period.

smaller migrants from south Florida and Mexico. Some of these smaller migrant fish may become year round residents of the northwest gulf as they grow larger.

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Age and Growth of King Mackerel, *Scomberomorus cavalla*, From the U.S. Gulf of Mexico

CHARLES S. MANOOCH, III, STEVEN P. NAUGHTON,
CHURCHILL B. GRIMES, and LEE TRENT

Introduction

The importance of king mackerel, *Scomberomorus cavalla*, to recreational and commercial fisheries along the southeastern Atlantic and Gulf of Mexico coasts of the United States has been thoroughly documented (Manooch et al., 1978; Manooch, 1979; Collette and Russo, 1984). Unfortunately, the importance of this coastal migratory species and the need for large-scale, regionally coordinated research has not been recognized until recently[1,2]. Manooch et al. (1978) provided an annotated bibliography of four western Atlantic scombrids and concluded that there was missing or incomplete knowledge concerning recreational catch and effort, migratory patterns, stock identity, and large-scale life history studies. Fishermen, scientists, and fishery managers still recognize these as priority research areas critical to the management of king mackerel stocks which are judged to be heavily exploited along both coasts. The National Marine Fisheries Service, regional universities, and state conservation agencies have responded to this need and have initiated extensive research efforts under the Marine Fisheries Initiative (MARFIN) Program.

Knowledge of age and growth is a life history aspect which is fundamental to resource management. Resulting data may be used to evaluate the impacts of fishing on the stocks or determine how they respond to different levels and strategies of fishing. Most studies on the age and growth of king mackerel have shared the deficiency of being restricted by either time or space (Manooch et al. 1978), however, Johnson et al. (1983) provided the most comprehensive geographic coverage.

Herein we report on an independent study on the Gulf of Mexico king mackerel management unit. The objectives were to: 1) Determine if rings on king mackerel otoliths were formed annually, 2) document the age and growth of the species in the Gulf of Mexico, 3) use sex specific otolith radii-fish length regressions to back-calculate fish length-at-age for the sexes, 4) derive theoretical growth equations for each sex, 5) generate more current age-length keys, and 6) estimate mortality from catch curves using sex specific age-length keys.

[1]Fishery management plan and environmental impact statement for coastal migratory pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic region, final amendment 1. 1985. Gulf of Mexico Fishery Management Council, Tampa, Fla., and South Atlantic Fishery Management Council, Charleston, S.C.

[2]A State/Federal plan to fill information needs for management of king mackerel resources in the southeastern United States. [Draft]. Gulf of Mexico Fishery Management Council, Gulf States Marine Fisheries Commission and National Marine Fisheries Service, King Mackerel Research Planning Meeting, New Orleans, January 6-7, 1986.

ABSTRACT—Whole otoliths of 1,098 king mackerel, Scomberomorus cavalla, *410-1,802 mm fork length (FL) were examined. The fish were sampled from recreational and commercial fisheries operating in the Gulf of Mexico from Key West, Fl., to the Yucatan Peninsula, Mex., from 1980 through 1985. Most fish were collected off Key West, northwest Florida, and Texas. The oldest fish was 14 years old and measured 1,802 mm FL. Rings formed on most otoliths during the late winter through spring (February-May) and are thus considered to be true annual marks. Back-calculated mean lengths of 947 fish ranged from 420 mm at age 1 to 1,269 mm FL at age 14. Females live longer and attain larger sizes than males. The von Bertalanffy growth equation for both sexes combined is* $L_t = 1{,}478\ (1 - e^{-0.1154(t + 2.3599)})$, *where* L = *fork length and* t = *years. The equation for females is* $L_t = 1{,}417\ (1 - e^{-0.1360(t+1.9754)})$, *and for males is* $L_t = 1{,}113\ (1 - e^{-0.2080(t + 1.4808)})$. *King mackerel are fully recruited to the gillnet and purse-seine fisheries of south Florida at age 2, to the recreational hook and line fishery off northwest Florida at ages 1 or 2, and to the Texs recreational hook and line fishery at ages 2 or 3. Total instantaneous mortality estimates (Z) ranged 0.53-0.82 for south Florida gillnet caught mackerel, 0.46-1.01 for northwest Florida hook and line fish, and 0.29-0.47 for fish caught by recreational hook and line off Texas. Mortality estimates were always lower for females than males for any area, gear, or month comparisons.*

Materials and Methods

King mackerel were sampled from recreational and commercial fisheries operating in the Gulf of Mexico from Key West, Fla., to the Yucatan Peninsula, Mex., from 1980 to 1985. Saggital otoliths from 1,098 fish were used in the study, and most were removed from king mackerel sampled off Key West, northwest Florida, and Texas (Table 1). Fork lengths (mm) were recorded for all fish,

Charles S. Manooch, III, is with the Beaufort Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Beaufort, NC 28516-9722. Steven P. Naughton, Churchill B. Grimes, and Lee Trent are with the Panama City Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Panama City, FL 32407.

Table 1.—Areas where king mackerel were collected.

Collection area	No. of fish	Collection area	No. of fish
S. Florida (Keys)	375	Mississippi Delta	4
N.W. Florida	506	Mexico	11
Alabama	1	Gulf of Mexico	3
Mississippi	5	Total	1,098
Lousiana	10		
Texas	182		

and weight and sex were determined when time and conditions permitted.

Whole otoliths were immersed in clove oil, placed in a black-bottom watchglass illuminated by reflected light, and examined at 50X through a dissecting microscope. After counting the number of rings, we measured distances from the otolith core to the distal edge of each ring, from the core to the otolith edge, and from the last ring to the otolith edge. We used the same plane of measurement as Johnson et al. (1983). We also prepared transverse sections about 0.7 mm thick using a Beuler[3] low-speed jewelers' saw from some otoliths embedded in black parafin. No annular measurements were made on otolith sections because the equidistant spacing of the outer rings on older fish may suggest a decoupling or changing relationship between otolith growth and fish growth in old age, thus making annular measurement of questionable use for back calculation of size-at-age (C.B. Grimes, personal commun.).

The time of ring formation was evaluated in two ways: 1) Plotting the distance from the last ring to the otolith edge by month, and 2) plotting the frequency of otoliths with marginal rings by month. In addition, we plotted core-to-ring measurements to determine if ring formation was consistent for different age groups.

To determine the relationship of the size of the otolith (OR) to the size of the fish (FL), we used least square regressions of power curves: $FL = aOR^b$. Equations were developed for both sexes combined, as well as for males and females separately using a stratified sample of 210 otoliths. All otoliths samples were ordered by fish length, from smallest to largest, and a random sample was drawn from each 100 mm interval until the 210 samples had been selected. This set was used to derive the overall equation, and when sex was assigned to each sample, then two subsets were identified, one for each sex (N = 122 for females, N = 88 for males). Once the relationships were obtained, fish sizes at earlier ages were back-calculated (Everhart et al., 1975; Ricker, 1975).

The von Bertalanffy growth equation $L_t = L_\infty\ (1 - e^{-K(t - t_0)})$ was fitted to back-calculated lengths using the Marquardt nonlinear iterative procedure (SAS Institute, 1982) to obtain estimates for L_∞, K, t_0, and their respective asymtotic 95 percent confidence intervals. Overall and sex specific back-calculated data were used to derive growth equations for both sexes combined (overall), for all females, for all males, and for females aged 1-10 years, and for males aged 1-9 years. The latter two groups enabled comparison of our results with Johnson et al. (1983) who fitted growth equations using the same ages.

We estimated total annual mortality by analyzing catch curves (Beverton and Holt, 1957) based on fully recruited age fish and older. If the $\log_e$ of the age frequency in the catch is plotted on age, the slope of the descending right limb of the curve is equal to the mean instantaneous rate of total annual mortality (Z) assuming constant recruitment and survival (Everhardt and Youngs, 1981). To calculate mortality rates for different fishing areas and gears for males, females, and sexes combined we constructed three age-length keys (i.e. the distribution of ages at 50 mm FL intervals) following Ricker (1975): One for both sexes combined, one for females, and one for males. Age-length keys were then applied as appropriate to randomly collected length frequency data for specific areas, gears and sexes.

Results and Discussion

Age

Whole otoliths were excellent for aging king mackerel. Rings were usually distinct and easily counted and measured. We selected whole otoliths since they were easier to prepare than sections, and because Johnson et al. (1983) found little difference in ages determined from sections with those obtained by reading whole structures. They compared age estimations based on sectional and surface readings of fish 0+ to 14+ years old and found 96.5 percent agreement. We conducted our own test by counting rings on sections and on whole otoliths from the same fish. Readings of age structures from 24 of the larger fish (950-1250 mm FL) revealed 87 percent agreement. Of the 1,098 whole otoliths we examined, 89.7 percent (985) could be aged, and 86.2 percent (947) were legible enough to record measurements for back calculations. Most of those not legible had been either stored in glycerin or left in fish that had rotted due to electric freezer failure. Some of the latter otoliths were salvaged, however, by soaking them in ethanol prior to immersing them in clove oil. Legibility of this group improved from less than 20 percent to >60 percent by using this procedure.

The usefulness of any hard structure to estimate fish age should first be proven. Critical to this decision is that there must be a positive relationship between the size of the fish and the size of the structure, and age marks must be periodically formed and consistently located on the hard part. Four observations support the use of whole otoliths for aging king mackerel and validate rings as annual marks. First, the mean lengths of fish progressively increased as the number of rings (age) increased. Second, there was a strong correlation between otolith radii and fish lengths ($r = 0.97$). Third, marginal increment analyses and plots of percentages of otoliths with marginal rings by month, generally showed a peak in ring formation from February through May (Fig. 1). And last, plots of the focus-to-ring measurement revealed a single mode for each ring, consistent specific ring location for different age groups (Fig. 2, 3), and the modes had increasing overlap with age. This is the first report in which all of these conditions have been satisfied for king mackerel. Beaumariage (1973) and Johnson et al. (1983) also studied the age and growth of the species in the Gulf of Mexico, but their marginal increment analy-

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

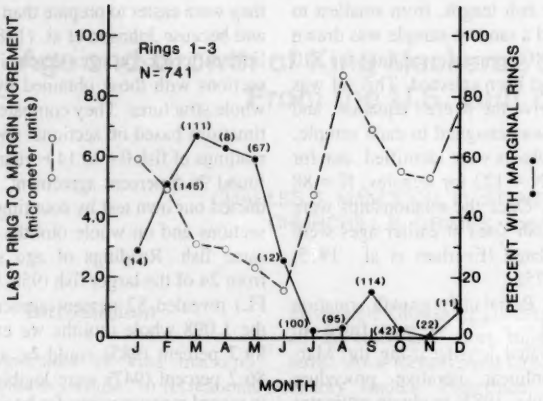

Figure 1.—Distance from the last ring to the otolith margin, and percentage of otoliths with marginal rings, by month, for fish with 1-3 rings.

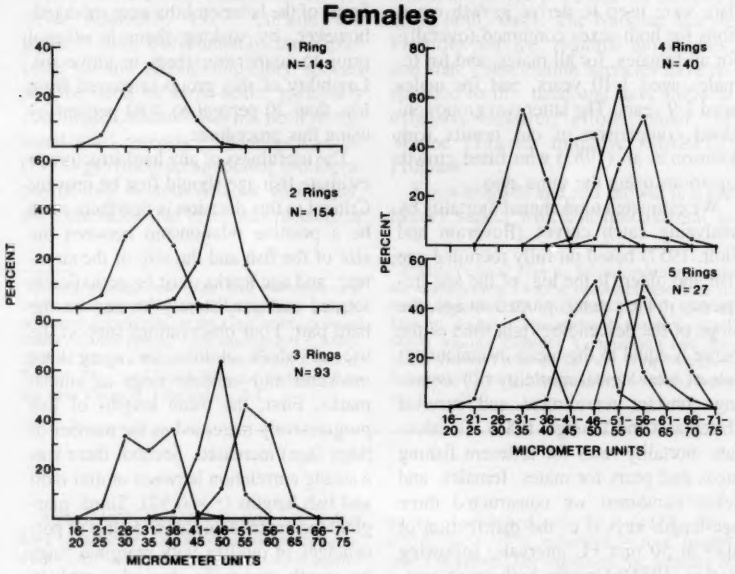

Figure 2.—Otolith focus-to-ring measurements for female king mackerel aged 1-5 years.

ses were not as conclusive. Beaumariage suggested ring formation in April, May, and June, and Johnson et al. reported May as the month when most rings were deposited. However, both studies included little or no data for the months of reported ring formation.

About 77 percent of the 985 fish we aged were ages 1-3 (26.8 percent age 1, 34.4 percent age 2, and 15.6 percent age 3). Johnson et al. (1983) found 70.21 percent of the fish to be 1-3 years old, excluding Louisiana samples. In both studies, females dominated age groups older than age 6. About 90 percent of our fish 1,000 mm FL or larger were females.

Back-Calculated Growth

Lengths at age were back calculated using three otolith radius-fish length regressions:

$FL = 7.002\ OR^{1.674}$, N = 210, r = 0.970 for both sexes combined,
$FL = 6.745\ OR^{1.1778}$, N = 122, r = 0.966 for females, and
$FL = 7.835\ OR^{1.1369}$, N = 88, r = 0.968 for males.

By substituting the means of the distance from the core to each annulus for *OR* in the above equations, we calculated the mean fish length at the time of each annulus formation, and the mean annual growth increment at each age for all fish, and by sex (Tables 2-4).

Growth in length was relatively fast for the first 3 years of life, but declined thereafter, and substantial annual growth was evident through age 14 (Table 2). Annual increments for the first 3 years for males and females combined were 420, 206, and 97 mm, respectively, and fell to only 34 mm at age 14. Annual increments for females were greater than for males (Tables 3, 4). Johnson et al (1983) found annual increments for the first 3 years for females to be 434, 218, and 95 mm, whereas ours were 425, 210, and 103 mm. Their increments for males were 414, 199, and 76 mm compared with 415, 199, and 84 mm for our samples. Thus, age and growth results between these two studies were almost identical for the age groups comprising the bulk of the fishery.

To analyze the similarity of these studies further, we compared data from Johnson et al. (1983) (Tables 7, 8) with our Tables 3 and 4 (Fig. 4, 5). Sample sizes in both studies are substantial for females aged 1-7 years and for males aged 1-6 years. Age and growth results are very similar for these age groups. In fact, for ages 1-5, which include 90-94 percent of all fish aged, the mean back-calculated lengths are almost identical (Fig. 4, 5). As females exceed aged 7 and males exceed age 6, mean-lengths at age become

progressively dissimilar. The differences in Johnson, et al. (1983) and our lengths at age for older fish may be primarily attributable to small sample sizes in those age groups in the former study. We conclude that our lengths for older fish better represent growth in later life for the species because we have larger sample sizes in those age groups. Beaumariage (1973) reported much larger mean back-calculated lengths for ages 1-3 for king mackerel in Florida, but his reported lengths for older fish were more similar to ours than to that of Johnson et al. (1983) (Table 5). The Beaumariage (1973) data were converted from standard lengths to fork lengths for this comparison.

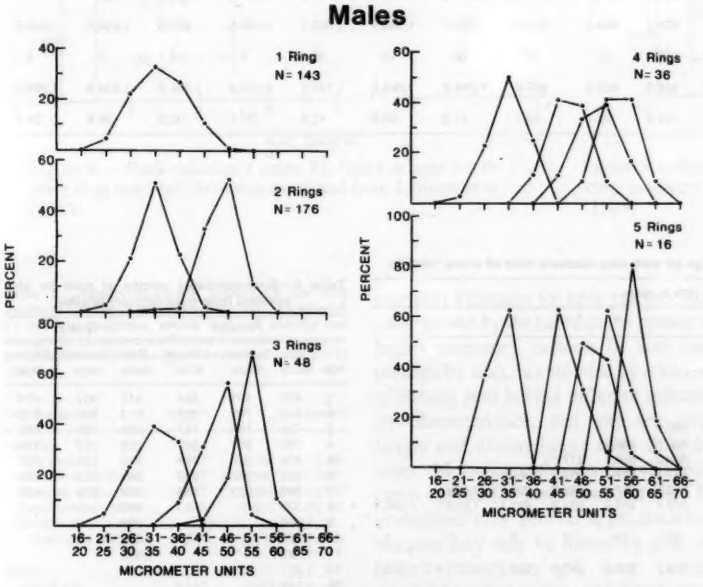

Figure 3.—Otolith focus-to-ring measurements for male king mackerel aged 1-5 years.

Theoretical Growth

Theoretical growth models provide growth parameters such as asymptotic size (L_∞), and growth coefficient (K) that may be used in constructing dynamic pool yield models. The most frequently used curve is the von Bertalanffy equation: $L_t = L_\infty (1 - e^{-K(t - t_0)})$, where L_t = length at age t (usually in years), and t_0 = time when fish are 0 length according to the fitted curve. The curve was fitted to back-calculated lengths (Everhart et al., 1975; Ricker, 1975) using Marquardt's nonlinear iterative procedure, and growth parameter estimates with 95 percent asymptotic confidence intervals (C.I.) were obtained for all fish, for females, and for males (Table 6):

$L_t = 1{,}478\ (1 - e^{-0.1154(t + 2.3599)})$ for both sexes combined,

$L_t = 1{,}417\ (1 - e^{-0.1360(t + 0.9754)})$ for females, and

$L_t = 1{,}113\ (1 - e^{-0.2080(t + 1.4808)})$ for males.

We also derived growth parameters for females aged 1-10 years and for males aged 1-9 years so that the parameters could be compared with Johnson et al. (1983), who used similar data (i.e. younger fish) to derive their models. Even with restricted ages, our models predicted larger fish for older age groups.

Theoretical fitted growth parameters for females and males and back calcu-

Table 2.—Average back-calculated fork lengths (mm) at age for king mackerel from all areas, 1980-85.

		Age in years													
Age	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	261	418.3													
2	336	417.4	631.6												
3	145	420.6	627.9	740.0											
4	77	425.8	608.8	701.8	774.2										
5	44	408.6	619.5	714.5	779.5	836.0									
6	28	422.8	614.7	712.3	783.0	844.8	893.7								
7	20	440.7	631.6	722.1	791.7	852.4	903.9	945.1							
8	10	432.6	600.6	707.1	782.1	850.0	897.4	945.1	981.5						
9	14	439.1	621.3	716.7	783.3	857.0	910.6	967.2	1,010.0	1,050.6					
10	5	432.6	636.3	734.1	811.1	869.5	935.2	984.8	1,034.9	1,075.1	1,112.2				
11	4	418.6	584.3	749.2	833.8	903.1	960.8	1,002.3	1,039.9	1,081.9	1,115.6	1,149.5			
12	2	444.4	658.2	737.3	817.6	882.6	940.1	998.1	1,039.9	1,081.9	1,132.5	1,166.5	1,209.2		
13															
14	1	400.3	565.1	673.9	737.3	801.4	866.3	915.4	998.1	1,048.3	1,098.7	1,149.5	1,200.6	1,234.9	1,269.3
Number		947	686	350	205	126	84	56	36	26	12	7	3	1	1
Weighted means		419.7	625.9	723.1	782.2	847.7	905.8	959.6	1,010.2	1,062.4	1,115.6	1,154.4	1,206.3	1,234.9	1,269.3
Annual increment		419.7	206.2	97.2	59.1	65.5	58.1	53.8	50.6	52.2	53.2	38.8	51.9	28.6	34.4

Table 3.—Average back-calculated fork lengths (mm) at age for female king mackerel from all areas, 1980-85.

Age	N	Age in years 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	143	436.0													
2	154	413.3	642.5												
3	93	422.0	637.6	756.8											
4	39	428.1	614.5	712.6	789.0										
5	27	413.9	623.9	723.0	792.1	850.3									
6	16	417.3	624.7	724.2	797.1	861.8	910.6								
7	11	472.9	654.5	741.7	817.2	878.5	936.1	980.5							
8	8	438.7	601.1	714.2	795.2	865.0	914.8	962.8	1,000.7						
9	8	447.9	640.4	734.3	817.6	883.5	939.8	1,000.7	1,045.3	1,092.2					
10	4	429.3	644.4	744.3	825.8	883.5	950.2	1,004.9	1,055.9	1,098.6	1,137.2				
11	3	409.6	581.6	772.7	865.6	932.1	993.6	1,038.8	1,078.5	1,118.6	1,153.1	1,187.7			
12	2	444.4	658.2	737.3	817.6	882.6	940.1	998.1	1,039.9	1,081.9	1,132.5	1,166.5	1,209.2		
13															
14	1	400.3	565.1	673.9	737.3	801.4	866.3	915.4	998.1	1,048.3	1,098.7	1,149.5	1,200.6	1,234.9	1,269.3
Number		509	366	212	119	80	53	37	26	18	10	6	3	1	1
Weighted means		425.0	634.9	738.1	799.0	866.2	928.9	987.6	1,034.8	1,094.4	1,137.2	1,174.3	1,206.3	1,234.9	1,269.3
Annual increments		425.0	209.9	103.2	60.9	67.2	62.7	58.7	47.2	59.6	42.8	37.1	32.0	28.6	34.4

Table 4.—Average back-calculated fork lengths (mm) at age for male king mackerel from all areas, 1980-85.

Age	N	Age in years 1	2	3	4	5	6	7	8	9	10	11
1	110	395.9										
2	176	423.0	620.3									
3	48	420.6	609.6	709.7								
4	36	424.9	603.3	687.9	756.5							
5	16	406.5	609.6	695.0	751.7	803.0						
6	12	431.7	601.2	694.7	761.3	818.3	866.5					
7	8	406.5	612.5	699.8	759.4	813.7	856.7	894.0				
8	2	410.1	601.2	684.5	738.2	800.1	839.0	886.1	917.7			
9	6	429.2	596.3	692.1	758.7	818.3	867.7	917.7	957.3	989.1		
10	1	446.2	608.7	699.8	761.3	823.4	886.1	917.7	965.2	997.1	1,029.1	
11	1	446.2	593.7	684.5	745.9	823.4	870.4	901.9	933.5	981.1	1,013.1	1,045.1
Number		416	306	130	82	46	30	18	10	8	2	1
Weighted means		415.2	614.4	698.4	756.2	811.6	863.1	902.8	947.8	989.1	1,021.1	1,045.1
Annual increment		415.2	199.2	84.0	57.8	55.4	51.5	39.7	45.0	41.3	32.0	24.0

Table 5.—Back-calculated lengths at ages for king mackerel from three different studies.

Age	Females This study	Females Beaumariage	Females Johnson et al.	Males This study	Males Beaumariage	Males Johnson et al.
1	425	491	434	415	457	414
2	635	703	652	614	643	613
3	738	793	747	698	705	689
4	799	857	807	756	752	734
5	866	928	854	812	795	777
6	929	986	899	863	822	809
7	988	1,033	939	903	839	851
8	1,035			948		
9	1,094			989		
10	1,137			1,021		
11	1,174			1,045		
12	1,201					
13	1,235					
14	1,269					

Table 6.—Theoretical growth parameters for different sex and age categories.

Category	Parameters L_∞	95% C.I.	K	95% C.I.	t_0	95% C.I.
All sexes, all ages	1,478	1,316-1,640	0.1154	0.0791-0.1517	−2.3599	−1.4367-3.2831
Females, ages 1-14	1,417	1,310-1,524	0.1360	0.1030-0.1690	−1.9754	−1.2718-2.6790
Males, ages 1-11	1,113	1,027-1,199	0.2080	0.1442-0.2718	−1.4808	−0.7224-2.2392
Females, ages 1-10	1,298	1,120-1,476	0.1719	0.0999-0.2439	−1.5481	−0.6404-2.4558
Males, ages 1-9	1,044	950-1,138	0.2578	0.1638-0.3518	−1.1198	−0.3731-1.8664

lated lengths at age for our study and for four others are given in Tables 7 and 8. Our estimated lengths at age for females appear most similar to those obtained by Ximenes et al. (1978) and Johnson et al. (1983) (Table 8).

Mortality and Age of Recruitment

The problems of obtaining reliable

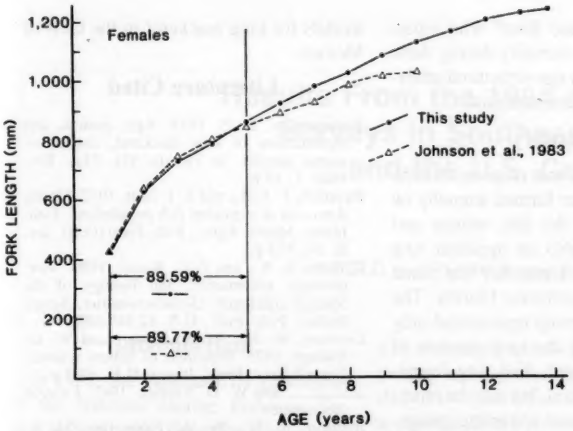

Figure 4.—Back-calculated mean FL (mm) at ages for female king mackerel from this study and from Johnson et al. (1983).

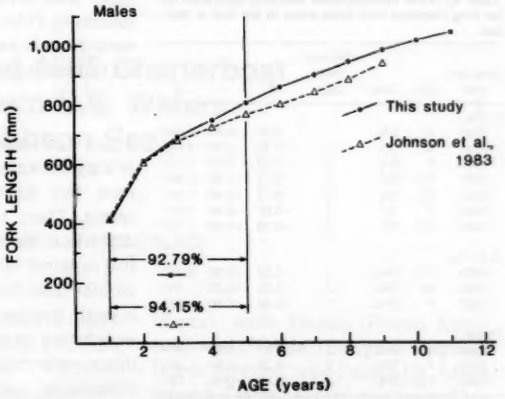

Figure 5.—Back-calculated mean FL (mm) at ages for male king mackerel from this study and from Johnson et al. (1983).

Table 7.—Theoretical growth parameters for king mackerel obtained from different studies. An asterisk (*) indicate parameter values that fall outside our asymptotic 95 percent confidence intervals for parameter estimates for females ages 1-14 and males ages 1-11 (Table 6).

Sex and source	L_∞ (mm FL)	K	t_0 (years)
Females			
This study	1,417	0.136	−1.98
Johnson et al. (1983)	1,067*	0.290*	−0.97
Ximenes et al. (1978)	1,317	0.164	−2.00[1]
Beaumariage (1973)	1,243	0.210	−2.40
Nomura and Rodriques (1967)	1,370	0.150	−0.13
Males			
This study	1,113	0.208	−1.48
Johnson et al. (1983)	965*	0.280	−1.17
Ximenes et al. (1978)	1,133	0.229	−1.50[1]
Beaumariage (1973)	903*	0.350	−2.50
Nomura and Rodriques (1967)	1,160	0.180	−0.22

[1]Assume negative.

mortality estimates for king mackerel are underscored by the fact that the species is highly migratory, schools by size (and perhaps by sex), is exploited by a variety of fishing gear having different selectivity characteristics, and one sex lives longer and attains larger sizes than the other. Mortality estimates derived from catch curves for king mackerel may be considered only general approximations because they may be biased by gear selectivity, such as gill nets, or the availability of certain sized individuals to fisheries over any given period of time. In addition, the principal assumptions of constant recruitment and survival may be questionable, because from 1980 to 1985 recruitment may have been declining and fishing mortality was certainly increasing (Scott and Burn[4],). To minimize these methodological problems we analyzed catch curve data for different fishing gear, different areas, and over different time intervals. We assumed that recreational hook-and-line data provided the best estimates of total instantaneous mortality, because only the very small fish would be excluded from the catch, and because angler catch and effort would best represent the ages of mackerel caught from many schools on many separate occasions.

Mortality estimates show considerable variation among years, gear types and areas (Table 9). Length frequency data from Trent et al.[5] were used to construct catch curves and estimate mortality. Ages when the species are fully recruited vary from age 1 to age 3 depending on fishing gear or area. Gill nets operating

Table 8.—Theoretical lengths at ages for king mackerel from five different studies.

	Females					Males				
Age	This study	Johnson et al. (1983)	Beaumariage (1973)	Nomura, Rodriques (1967)	Ximenes, et al. (1978)	This study	Johnson et al. (1983)	Beaumariage (1973)	Nomura, Rodriques (1967)	Ximenes, et al. (1978)
1	471.6	464.4	634.3	213.6	511.8	448.7	439.4	637.7	228.8	493.9
2	591.8	616.1	749.7	374.7	633.6	573.4	567.8	716.1	382.1	624.6
3	696.7	729.6	843.0	513.3	737.0	674.8	664.8	771.3	510.3	728.7
4	788.3	814.5	918.8	632.7	824.7	757.1	738.1	810.2	617.2	811.5
5	868.3	878.0	980.2	735.4	899.1	823.9	793.5	837.6	706.7	877.3
6	938.0	925.6	1,029.9	823.8	962.3	878.2	835.4	856.9	781.4	929.6
7	999.0	961.6	1,070.3	899.8	1,015.9	922.3	867.1	870.5	843.8	971.3
8	1,052.1	987.8	1,103.0	965.3	1,062.0	958.2	891.0	880.2	895.9	1,004.3
9	1,098.5	1,007.8	1,129.5	1,021.7	1,100.2	987.3	907.1	886.4	939.4	1,030.7
10	1,139.0	1,022.7	1,151.0	1,070.2	1,133.0	1,010.9		891.6	975.7	1,051.7
11	1,174.4		1,168.4	1,112.0	1,160.8	1,030.1			1,006.1	1,068.3
12	1,205.3		1,182.6	1,147.9	1,184.4					
13	1,232.2		1,194.0	1,178.9	1,204.5					
14	1,255.7		1,203.0	1,205.5	1,221.5					

[4]Scott, G. P., and D. M. Burn. 1987. Updated assessment information on the king mackerel resource in the southeastern United States. Miami Laboratory, NMFS Southeast Fisheries Center, Coastal Resources Div., Contr. ML-CRD-86/87-18. Unpubl. rep.

[5]Trent, L., M. Godcharles, B. J. Palko, L. A. Collins, and L. A. Trimble. Lengths of king mackerel, *Scomberomorus cavalla*, in the southeastern United States by area, capture, gear, year, month, and sex, 1968-1984. Panama City Laboratory, Southeast Fisheries Center, NMFS, NOAA, Panama City, Fla. Unpubl. manuscr.

Table 9.—Total instantaneous mortality estimates (Z) for king mackerel from three areas in the Gulf of Mexico.

Area and year	Sex	Gear[1]	Recruitment age	Z	r	N
S. Fla.						
1980	U	GN	2	−0.53	−0.98	1,600
1981	M	GN	2	−0.82	−0.96	1,845
1981	F	GN	2	−0.63	−0.99	1,117
1981	Tot.	GN	2	−0.72	−0.99	2,962
1984	M	GN	2	−0.73	−0.96	1,261
1984	F	GN	2	−0.60	−0.99	1,577
1984	Tot.	PS	2	−0.50	−0.99	192
N.W. Fla.						
1980	Tot.	RHL	1	−0.54	−0.95	6,732
1980	M	RHL	2	−1.01	−0.95	316
1980	F	RHL	1	−0.46	−0.90	531
Texas						
1980	M	RHL	2	−0.47	−0.95	314
1980	F	RHL	3	−0.29	−0.90	301
1980	Tot.	RHL	2	−0.42	−0.95	731

[1]GN = gill net, PS = purse seine, RHL = recreational hook and line.

off south Florida always recruited age 2 fish, whereas recreational hook and line caught mackerel were recruited at age 1 and age 2 off northwest Florida, and at age 2 and age 3 off Texas (Table 9). Although varying by gear and area, mortality estimates for males were always greater than for females. Values were lowest for recreational hook-and-line (RHL) fish off Texas ($Z = 0.29$-0.47), intermediate for RHL caught fish off northwest Florida ($Z = 0.46$-1.01), and highest for king mackerel captured by gill nets off south Florida ($Z = 0.53$-0.82). Although the catch-curve method provides approximate mortality estimates, our results are apparently robust in that they show a generally increasing trend in total mortality with time. Our results agree with Scott and Burn[4] who report increasing fishing mortality during these same years from an age-structured analysis (virtual population analysis).

Summary

Our data indicate that rings on otoliths of king mackerel are formed annually on most fish during the late winter and spring. There is also an apparent ring deposition during September for some fish captured off northwest Florida. The otoliths from this group represented only a small fraction of the total number of otoliths we examined. Fall ring formation is yet unexplained, but may be representative of a separate spawning group.

The dominant age groups of king mackerel caught throughout the Gulf of Mexico were ages 1-3. In catch curves derived for fish collected off Key West, Fl., northwest Florida, and Texas, percentages of age groups 1-3 ranged from 42.5 to 94.9 (weighted mean = 78.0 percent; 17,457 of 22,375 fish). Fish aged 4-7 years were also relatively common, and those older than age 7 were rare. Our study and that by Johnson et al. (1983) adequately describe the growth of king mackerel aged 1-7 years, the age groups that actually support commercial and recreational fisheries in the Gulf of Mexico. For older fish, our data and those of Ximenes et al. (1978) may be the best representation of growth. Because our data were more complete (i.e., larger sample size at older ages) and we used more exact (iterative) curve fitting procedures than earlier studies, our theoretical growth parameters represent an important data set and consideration should be given to using them to derive population models for king mackerel in the Gulf of Mexico.

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Results From the 1984 and 1985 Charterboat Surveys in Southeastern U.S. Waters and the U.S. Caribbean Sea

HAROLD A. BRUSHER and BARBARA JAYNE PALKO

ABSTRACT—In 1984 and 1985, surveys of southeastern U.S. waters, including the Gulf of Mexico and the U.S. Caribbean Sea, were conducted to gather catch and effort records from charterboat captains located along coastal areas. Captains were contracted to supply daily records of fishing activity. During the 2-year period, 10,380 fishing trips, 48,231 hours of fishing effort were expended and 342,258 fishes were caught. Species, catches, and catch-per-boat-fishing-hour (CPH) are presented by year, month, and area. Major species groups caught by trolling included mackerels and tunas (Scombridae), while other-than-trolling methods caught mostly snappers (Lutjanidae), groupers (Serranidae), and croakers (Sciaenidae). Annual response rates for returning log forms for the 1984 and 1985 surveys were 98.8 and 95.7 percent, respectively.

Introduction

In 1982, the Panama City Laboratory of the National Marine Fisheries Service's Southeast Fisheries Center initiated a catch and effort survey of charterboat captains (Brusher et al., 1984). Charterboat captains are an easily identifiable component of marine recreational fisheries; their livelihood depends on a high frequency of fishing trips and repeated angling success. The charterboat survey, with some modifications, has been run annually with each year's results finalized by mid-February of the following year (Williams et al., 1984a, b, 1985; Brusher and Palko, 1986). The computerized data were subjected to continuous quality control. The result was a reporting system designed to provide data relatively quickly. The objectives of these surveys were to determine the relative abundance and distribution of coastal pelagic and demersal fishes by collecting daily catch and effort data (CPUE) from a segment of the recreational fishery.

This report describes the 1984 and 1985 surveys and examines the catch and effort data submitted by charterboat captains located along coastal areas of the southeastern United States and the U.S. Caribbean Sea.

Methods

The 1984 survey (Fig. 1) did not cover the 16 areas that were sampled in 1983, but involved captains located in the following coastal areas: North Carolina, east Florida (Daytona Beach through Ft. Pierce), southeast Florida (Stuart through Miami), south Florida (Florida Keys), southwest Florida (Everglades through Bonita Springs), west Florida (Ft. Myers through Crystal River), northwest Florida (Cedar Key through Pensacola), Louisiana, south Texas (Rockport through Port Isabel), and the U.S. Caribbean (Puerto Rico, U.S. Virgin Islands). In 1985, all 16 areas were sampled. The selection of, and the contractual agreements with, these captains have been described by Brusher and Palko (1985).

In both 1984 and 1985, the surveys

The authors are with the Panama City Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407.

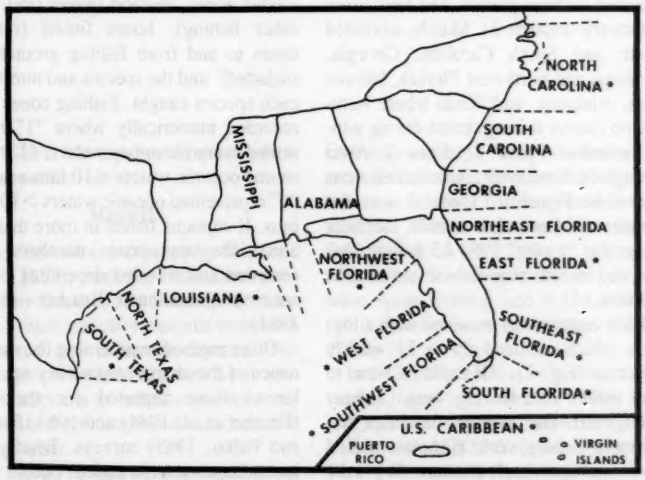
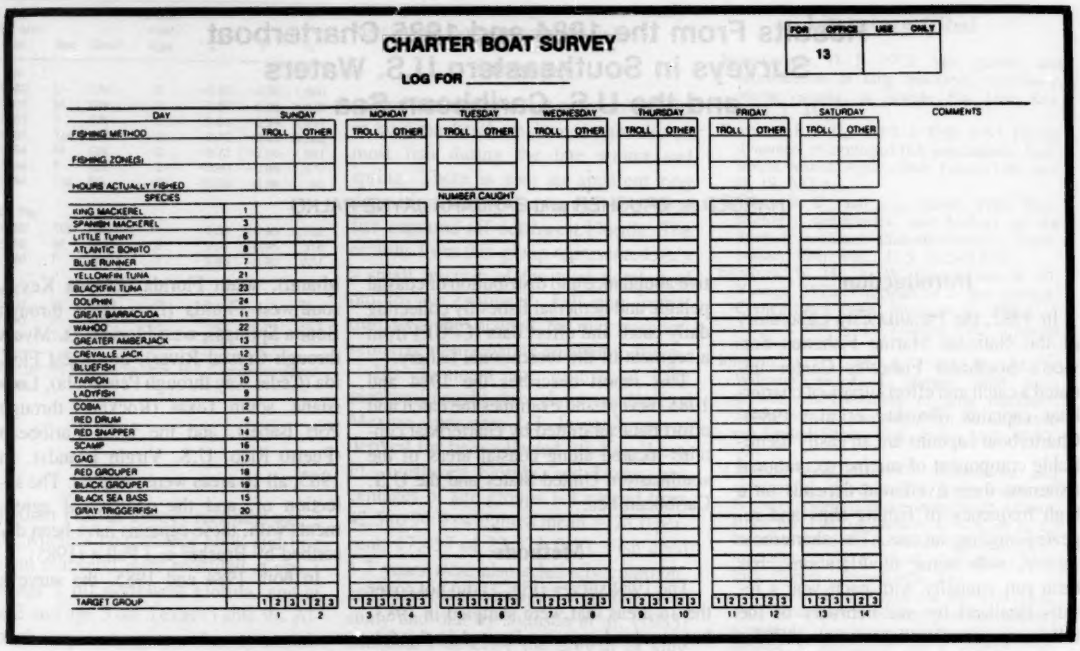


Figure 1.—Coastal areas used in reporting 1984 (*) and 1985 charterboat catch and effort from southeastern U.S. waters, the Gulf of Mexico, and the U.S. Caribbean Sea.



CHARTER BOAT SURVEY

LOG FOR _____

FOR OFFICE USE ONLY
13

DAY	SUNDAY		MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		SATURDAY		COMMENTS
FISHING METHOD	TROLL	OTHER	TROLL	OTHER	TROLL	OTHER	TROLL	OTHER	TROLL	OTHER	TROLL	OTHER	TROLL	OTHER	
FISHING ZONE(S)															
HOURS ACTUALLY FISHED															
SPECIES					NUMBER CAUGHT										
KING MACKEREL 1															
SPANISH MACKEREL 3															
LITTLE TUNNY 6															
ATLANTIC BONITO 8															
BLUE RUNNER 7															
YELLOWFIN TUNA 21															
BLACKFIN TUNA 23															
DOLPHIN 24															
GREAT BARRACUDA 11															
WAHOO 22															
GREATER AMBERJACK 13															
CREVALLE JACK 12															
BLUEFISH 5															
TARPON 10															
LADYFISH 9															
COBIA 2															
RED DRUM 4															
RED SNAPPER 14															
SCAMP 16															
GAG 17															
RED GROUPER 18															
BLACK GROUPER 19															
BLACK SEA BASS 15															
GRAY TRIGGERFISH 20															
TARGET GROUP	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Figure 2.—Logform used in both 1984 and 1985 charterboat surveys.

operated in three phases. The first, from 1 January through 31 March, excluded North and South Carolina, Georgia, northeast and northwest Florida, Mississippi, Alabama, and Texas where virtually no charter fishing occurs during winter months. Phase 2, from 1 April through 30 November, included all areas shown in Figure 1. Phase 3 was the month of December which actually began the "winter" 1984-85 fishing season, and included the same seven areas as in Phase 1.

Each captain was provided with a logbook which included up to 52 weekly logforms (Fig. 2). All captains were to mail results of a fishing week (Sunday through Saturday) within 7 days after that particular fishing week. If captains failed to respond in a timely manner, they were replaced by random selection from a list of cooperative captains in their area.

Collected data for each fishing day included zones, method (either trolling or other fishing), hours fished (running times to and from fishing grounds not included), and the species and number of each species caught. Fishing zones were recorded numerically where "1" represented estuarine or bay waters, "2" represented oceanic waters ≤10 fathoms, and "3" represented oceanic waters >10 fathoms. If captains fished in more than one zone, the appropriate numbers were recorded and recoded depending on the zone combinations (Brusher et al., 1984).

Other methods concerning the maintenance of the charterboat survey are similar to those reported for the 1982 (Brusher et al, 1984) and 1983 (Brusher and Palko, 1985) surveys. Briefly, the incoming data were coded, put on computer, proofed, and archived for future analysis.

During the 1984-85 charterboat surveys, a monthly newsletter, "Channel 68", was produced by project personnel and sent to all participating captains as well as other interested correspondents. This newsletter summarized the previous month's catch-per-boat-hour (CPH) data and reported CPH by fishing method per survey area for the top five species. CPH data were computed from total hours fished and total species caught during a specific period in a particular area (e.g., total caught divided by total fishing hours). "Channel 68" was also a medium that project personnel used to discuss problems in identification and the recording of catches.

Charterboat Characteristics

In both surveys, our definition of a charterboat was a vessel at least 25 feet in length that was available for hire and included the services of a licensed captain. Surveyed charterboats generally carried

Table 1.—Total fishing hours by area, zone, and method of fishing during the 1984 charterboat survey off the southeastern United States and in the U.S. Caribbean Sea.

Area	Hours trolling and other fishing[1] by fishing zones							
	1 Estuarine	2 Oceanic (<10 fm)	3 Oceanic (>10 fm)	4 Estuarine and oceanic (<10 fm)	5 Estuarine and oceanic (>10 fm)	6 Oceanic (all depths)	7 Estuarine and oceanic (all depths)	Totals
North Carolina	23.0 (–)[2]	811.0 (8.5)	904.5 (88.0)	– (–)	3.0 (–)	36.0 (–)	– (–)	1,777.5 (96.5)
Florida (E)	2.0 (–)	24.0 (6.0)	764.5 (353.5)	– (1.5)	– (–)	1,477.5 (15.0)	– (–)	2,268.0 (376.0)
Florida (SE)	– (–)	6.0 (–)	646.5 (173.0)	– (–)	– (–)	94.0 (4.0)	– (–)	746.5 (177.0)
Florida (S)	– (19.5)	271.5 (54.0)	2,064.0 (231.0)	– (–)	– (–)	441.5 (5.5)	7.0 (–)	2,784.0 (310.0)
Florida (SW)	– (786.0)	38.5 (296.5)	– (203.5)	– (109.5)	– (–)	– (–)	– (–)	38.5 (1,395.5)
Florida (W)	13.5 (407.5)	1,156.5 (543.0)	73.0 (110.5)	29.0 (17.5)	– (–)	292.0 (9.0)	– (–)	1,564.0 (1,087.5)
Florida (NW)	65.0 (7.0)	245.5 (111.5)	156.0 (926.0)	4.0 (–)	– (–)	– (9.5)	– (–)	470.5 (1,054.0)
Louisiana	– (9.0)	75.5 (25.0)	184.0 (2,231.5)	– (–)	– (4.0)	11.0 (90.5)	– (–)	270.5 (2,360.0)
Texas (S)	– (22.0)	24.0 (61.0)	810.0 (1,225.5)	– (–)	– (–)	24.0 (–)	– (–)	858.0 (1,308.5)
U.S. Caribbean	2.0 (–)	– (–)	3,347.0 (–)	– (–)	– (–)	– (–)	– (–)	3,349.0 (–)
Totals	105.5 (1,251.0)	2,652.5 (1,105.5)	8,949.5 (5,542.5)	33.0 (128.5)	3.0 (4.0)	2,376.0 (133.5)	7.0 (–)	14,126.5 (8,165.0)

[1]Other fishing data is given in parentheses.
[2]Dashes indicate no effort within this fishing zone for this area.

Table 2.—Total fishing hours by area, zone, and method of fishing during the 1985 charterboat survey off the southeastern United States and in the U.S. Caribbean Sea.

Area	Hours trolling and other fishing[1] by fishing zones						
	1 Estuarine	2 Oceanic (<10 fm)	3 Oceanic (>10 fm)	4 Estuarine and oceanic (<10 fm)	5 Estuarine and oceanic (>10 fm)	6 Oceanic (all depths)	Totals
North Carolina	7.5 (–)[2]	134.5 (47.0)	1,491.0 (37.5)	– (–)	– (–)	4.5 (–)	1,637.5 (84.5)
South Carolina	14.5 (8.0)	172.5 (31.0)	339.5 (1.0)	– (–)	– (–)	31.0 (–)	557.5 (40.0)
Georgia	16.0 (84.0)	114.5 (155.0)	58.0 (71.5)	– (–)	– (–)	– (–)	188.5 (310.5)
Florida (NE)	9.0 (182.0)	152.5 (99.5)	186.0 (52.5)	21.0 (–)	– (–)	167.5 (–)	536.0 (334.0)
Florida (E)	– (5.0)	13.0 (35.5)	663.5 (367.5)	– (–)	– (–)	951.0 (103.0)	1,627.5 (511.0)
Florida (SE)	– (3.0)	18.0 (14.0)	1,261.0 (484.0)	– (4.0)	– (–)	41.0 (9.0)	1,320.0 (514.0)
Florida (S)	– (38.5)	283.5 (142.0)	1,457.5 (354.5)	– (–)	3.0 (–)	413.0 (128.5)	2,157.0 (663.5)
Florida (SW)	– (861.0)	36.0 (319.5)	– (363.0)	– (86.0)	– (–)	– (–)	36.0 (1,629.5)
Florida (W)	– (–)	912.0 (667.0)	143.5 (375.5)	– (–)	– (–)	17.0 (40.0)	1,072.5 (1,082.5)
Florida (NW)	125.5 (–)	56.5 (66.5)	167.0 (1,396.0)	4.0 (3.0)	6.0 (–)	– (9.5)	359.0 (1,475.0)
Alabama	2.0 (2.0)	148.0 (24.5)	75.0 (398.5)	16.0 (3.0)	222.0 (8.0)	121.0 (20.5)	584.0 (456.5)
Mississippi	5.0 (3.5)	678.0 (261.0)	26.5 (47.5)	– (–)	– (–)	– (–)	709.5 (312.0)
Louisiana	11.0 (–)	222.5 (–)	199.5 (805.5)	– (–)	– (–)	34.5 (17.0)	467.5 (822.5)
Texas (N)	– (22.0)	118.0 (99.0)	328.5 (168.5)	12.0 (3.0)	– (–)	324.0 (13.5)	782.5 (306.0)
Texas (S)	19.0 (190.5)	600.0 (66.5)	688.0 (21.0)	12.5 (–)	– (–)	79.5 (8.5)	1,399.0 (286.5)
U.S. Caribbean	– (–)	7.5 (–)	3,670.0 (–)	– (–)	– (–)	– (–)	3,677.5 (–)
Totals	209.5 (1,399.5)	3,667.0 (2,028.0)	10,754.5 (4,944.0)	65.5 (99.0)	231.0 (8.0)	2,184.0 (349.5)	17,111.5 (8,828.0)

[1]Other fishing data is given in parentheses.
[2]Dashes indicate no effort within this fishing zone for this area.

up to six fishermen, trolled no more than four lines, and bottom fished using from six to eight lines. This definition described vessel characteristics for most surveyed areas, especially where running times to offshore fishing grounds (>10 fathoms) were short. However, in areas such as Louisiana, where running times to deeper depth zones were often 2-3 hours, some charterboats carried 10-20 passengers, especially when using "other fishing" methods. These "other fishing" methods included bottom fishing, flylining, or drift fishing whereby unweighted live or dead bait were fished from anchored or drifting vessels. Bottom fishing, where weighted live or dead baits were fished, was the most frequent other-fishing method used.

Results

The 1984 data, published by Williams et al. (1985), and the 1985 data, published by Brusher and Palko (1986), included catch and effort records from both contracted and volunteer captains. For this paper, we used only data from contracted captains to indicate species composition and species abundances between fishing areas.

In 1984, 51 charterboat captains reported their catches and effort from 4,676 trips. They submitted 1,241 weekly logs of the 1,255 total possible logs (98.9 percent response rate). A trip was defined as an absence from a dock during which at least one of two fishing methods was used in a 24-hour day. Captains reported fishing a total of 22,291.5 hours, of which 14,126.5 hours (63.4 percent) were spent trolling and 8,165.0 hours (36.6 percent) were spent other fishing (Table 1).

In 1985, 57 captains submitted 1,639 weekly logs, and reported 5,704 trips (94.3 percent response rate). They fished a total of 25,939.5 hours, of which 17,111.5 hours (66.0 percent) were spent trolling and 8,828.0 hours (34.0 percent) were spent other fishing (Table 2).

The 1984 data showed that 6.1 percent

Table 3.—Number of each species making up at least 0.5% of the total caught by trolling during the 1984 charterboat survey off the southeastern United States and the U.S. Caribbean.

Common name	Scientific name	Catch	Percent of total catch	Common name	Scientific name	Catch	Percent of total catch
Dolphin	*Coryphaena hippurus*	8,578	21.0	Yellowtail snapper	*Ocyurus chrysurus*	400	1.0
Spanish mackerel	*Scomberomorus maculatus*	5,698	14.0	Wahoo	*Acanthocybium solanderi*	364	0.9
King mackerel	*Scomberomorus cavalla*	5,380	13.2	Greater amberjack	*Seriola dumerili*	333	0.8
Little tunny	*Euthynnus alletteratus*	4,784	11.7	Crevalle jack	*Caranx hippos*	318	0.8
Bluefish	*Pomatomus saltatrix*	3,064	7.5	Black sea bass	*Centropristis striata*	288	0.7
Great barracuda	*Sphyraena barracuda*	2,820	6.9	Skipjack tuna	*Euthynnus pelamis*	269	0.7
Blue runner	*Caranx crysos*	2,598	6.4	Cero	*Scomberomorus regalis*	215	0.5
Atlantic bonito	*Sarda sarda*	1,984	4.9	Black grouper	*Mycteroperca bonaci*	209	0.5
Blackfin tuna	*Thunnus atlanticus*	1,098	2.7	Sailfish	*Istiophorus platypterus*	207	0.5
Yellowfin tuna	*Thunnus albacares*	793	1.9	Total		39,399	96.6

Table 4.—Number of each species or species group making up at least 0.5 percent of the total caught by other fishing during the 1984 charterboat survey off the southeastern United States.

Common name	Scientific name	Catch	Percent of total catch	Common name	Scientific name	Catch	Percent of total catch
Sand seatrout	*Cynoscion arenarius*	55,574	34.9	Spotted seatrout	*Cynoscion nebulosus*	2,071	1.3
Atlantic croaker	*Micropogonias undulatus*	29,232	18.4	Dolphin	*Coryphaena hippurus*	1,795	1.1
Red snapper	*Lutjanus campechanus*	14,468	9.1	Gray snapper	*Lutjanus griseus*	1,435	0.9
Black sea bass	*Centropristis striata*	8,516	5.4	Grunts	Haemulidae	1,429	0.9
Seatrouts	*Cynoscion* spp.	8,417	5.3	Blue runner	*Caranx crysos*	1,275	0.8
King mackerel	*Scomberomorus cavalla*	3,474	2.2	Silver seatrout	*Cynoscion nothus*	1,232	0.8
Gray triggerfish	*Balistes capriscus*	3,337	2.1	Sheepshead	*Archosargus probatocephalus*	1,207	0.8
Greater amberjack	*Seriola dumerili*	3,264	2.1	Crevalle jack	*Caranx hippos*	1,202	0.8
Red drum	*Sciaenops ocellatus*	3,043	1.9	Red grouper	*Epinephelus morio*	1,123	0.7
Gag	*Mycteroperca microlepis*	2,546	1.6	Ladyfish	*Elops saurus*	1,063	0.7
Bluefish	*Pomatomus saltatrix*	2,378	1.5	Vermilion snapper	*Rhomboplites aurorubens*	1,047	0.7
Porgies	Sparidae	2,257	1.4	Total		146,405	95.4

Table 5.—Number of each species or species group making up at least 0.5 percent of the total caught by trolling during the 1985 charterboat survey off the southeastern United States and the U.S. Caribbean.

Common name	Scientific name	Catch	Percent of total catch	Common name	Scientific name	Catch	Percent of total catch
Spanish mackerel	*Scomberomorus maculatus*	11,864	21.9	Crevalle jack	*Caranx hippos*	843	1.6
Dolphin	*Coryphaena hippurus*	9,990	18.5	Red snapper	*Lutjanus campechanus*	774	1.4
King mackerel	*Scomberomorus cavalla*	9,183	17.0	Blackfin tuna	*Thunnus atlanticus*	593	1.1
Little tunny	*Euthynnus alletteratus*	4,943	9.1	Red drum	*Sciaenops ocellatus*	474	0.9
Blue runner	*Caranx crysos*	2,735	5.1	Cero	*Scomberomorus regalis*	429	0.8
Great barracuda	*Sphyraena barracuda*	2,658	4.9	Wahoo	*Acanthocybium solanderi*	397	0.7
Atlantic bonito	*Sarda sarda*	2,427	4.5	Black grouper	*Mycteroperca bonaci*	358	0.7
Yellowfin tuna	*Thunnus albacares*	2,014	3.7	Sharks	Squaliformes	290	0.5
Greater amberjack	*Seriola dumerili*	935	1.7	Total		51,752	95.7
Bluefish	*Pomatomus saltatrix*	845	1.6				

of the total fishing effort in all areas occurred in estuarine areas, 16.8 percent in oceanic waters ≤10 fathoms, 64.6 percent in oceanic waters >10 fathoms, and 12.5 percent in combinations of the above. The 1985 data showed that for all areas 6.2 percent of the total fishing occurred in estuarine waters, 22.0 percent in waters ≤10 fathoms, 60.5 percent in >10 fathoms, and 11.3 percent in combinations.

In 1984, trolling was the dominant fishing method used by charterboat captains off North Carolina (94.9 percent); east (85.8 percent), southeast (80.8 percent), west (59.0 percent), and south (90.0 percent) Florida; and the U.S. Caribbean (100 percent). Other fishing methods were used most frequently off southwest (97.3 percent) and northwest (69.1 percent) Florida, Louisiana (89.7 percent), and south Texas (60.4 percent).

Trolling was the prevalent fishing method in 1985 in North Carolina (95.1 percent), South Carolina (93.3 percent); northeast (61.6 percent), east (76.1 percent), southeast (72.0 percent), and south (76.5 percent) Florida; Alabama (56.1 percent), Mississippi (69.5 percent); north (71.9 percent) and south (83.0 percent) Texas; and the U.S. Caribbean (100.0 percent). Other fishing was the prevalent method in Georgia (62.2 percent); southwest (97.8 percent) and northwest (80.4 percent) Florida; and Louisiana (63.8 percent). West Florida fishing effort was almost equally divided between trolling (49.8 percent) and other fishing (50.2 percent).

Table 6.—Number of each species or species group making up at least 0.5 percent of the total caught by other fishing during the 1985 charterboat survey off the southeastern United States.

Common name	Scientific name	Catch	Percent of total catch	Common name	Scientific name	Catch	Percent of total catch
Sand seatrout	*Cynoscion arenarius*	14,817	16.8	Red drum	*Sciaenops ocellatus*	1,367	1.5
Red snapper	*Lutjanus campechanus*	7,693	8.7	Blue runner	*Caranx crysos*	1,310	1.5
Black sea bass	*Centropristis striata*	7,567	8.6	Ladyfish	*Elops saurus*	1,179	1.3
Gag	*Mycteroperca microlepis*	6,018	6.8	Sheepshead	*Archosargus probatocephalus*	1,151	1.3
Atlantic croaker	*Micropogonias undulatus*	5,634	6.4	Bluefish	*Pomatomus saltatrix*	1,030	1.2
Gray triggerfish	*Balistes capriscus*	4,873	5.5	Little tunny	*Euthynnus alletteratus*	973	1.1
Yellowtail snapper	*Ocyurus chrysurus*	3,542	4.0	King mackerel	*Scomberomorus cavalla*	908	1.0
Greater amberjack	*Seriola dumerili*	3,495	4.0	Atlantic bonito	*Sarda sarda*	899	1.0
Red grouper	*Epinephelus morio*	3,364	3.8	Sharks	Squaliformes	614	0.7
Porgies	Sparidae	3,022	3.4	Pinfish	*Lagodon rhomboides*	575	0.7
Gray snapper	*Lutjanus griseus*	3,019	3.4	Crevalle jack	*Caranx hippos*	565	0.6
Seatrouts	*Cynoscion* spp.	3,013	3.4	Lane snapper	*Lutjanus synagris*	509	0.6
Vermilion snapper	*Rhomboplites aurorubens*	2,894	3.3	Kingfishes	*Menticirrhus* spp.	456	0.5
Grunts	Haemulidae	1,959	2.2	Total		84,087	95.2
Spotted seatrout	*Cynoscion nebulosus*	1,641	1.9				

Table 7.—Ten most abundant species caught by trolling in each area off the southeastern United States and in the U.S. Caribbean during the 1984 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Bluefish	2,831	1.59	26.4
2 Spanish mackerel	2,465	1.39	23.0
3 King mackerel	1,825	1.03	17.0
4 Dolphin	1,717	0.97	16.0
5 Yellowfin tuna	618	0.35	5.8
6 Blue runner	459	0.26	4.3
7 Black sea bass	285	0.16	2.7
8 Little tunny	152	0.09	1.4
9 Albacore	106	0.06	1.0
10 Wahoo	48	0.03	0.4
	10,506		98.0
East Florida			
1 King mackerel	1,168	0.52	17.6
2 Little tunny	1,098	0.48	16.6
3 Dolphin	1,069	0.47	16.1
4 Blue runner	1,007	0.44	15.2
5 Great barracuda	806	0.36	12.2
6 Atlantic bonito	749	0.33	11.3
7 Spanish mackerel	135	0.06	2.0
8 Gag	122	0.05	1.8
East Florida cont.			
9 Bluefish	110	0.05	1.7
10 Greater amberjack	107	0.05	1.6
	6,371		96.1
Southeast Florida			
1 Dolphin	326	0.44	23.3
2 Atlantic bonito	191	0.26	13.6
3 Great barracuda	150	0.20	10.7
4 Spanish mackerel	140	0.19	10.0
5 Little tunny	136	0.18	9.7
6 Blue runner	102	0.14	7.3
7 King mackerel	89	0.12	6.4
8 Skipjack tuna	71	0.10	5.1
9 Sailfish	54	0.07	3.9
10 Bluefish	33	0.04	2.4
	1,292		92.4
South Florida			
1 Dolphin	4,211	1.51	46.2
2 Great barracuda	1,195	0.43	13.1
3 Blackfin tuna	829	0.30	9.1
South Florida cont.			
4 Atlantic bonito	668	0.24	7.3
5 King mackerel	523	0.19	5.7
6 Yellowtail snapper	397	0.14	4.4
7 Black grouper	184	0.07	2.0
8 Cero	141	0.05	1.5
9 Little tunny	138	0.05	1.5
10 Mutton snapper	110	0.04	1.2
	8,396		92.0
U.S. Caribbean			
1 Little tunny	528	0.16	28.5
2 King mackerel	351	0.10	19.0
3 Great barracuda	223	0.07	12.0
4 Dolphin	213	0.06	11.5
5 Blue marlin	140	0.04	7.6
6 Wahoo	85	0.03	4.6
7 Yellowfin tuna	65	0.02	3.5
8 Blackfin tuna	60	0.02	3.2
9 Cero	53	0.02	2.9
10 Skipjack tuna	48	0.01	2.6
	1,766		95.4

Table 8.—Ten most abundant species caught by trolling in each area of the Gulf of Mexico during the 1984 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Spanish mackerel	130	3.38	63.1
2 Bluefish	68	1.77	33.0
3 Unidentified seatrouts	8	0.21	3.9
	206		100.0
West Florida			
1 Spanish mackerel	2,098	1.34	46.0
2 Little tunny	729	0.47	16.0
3 King mackerel	677	0.43	14.9
4 Great barracuda	390	0.25	8.6
5 Atlantic bonito	168	0.11	3.7
6 Blue runner	161	0.10	3.5
7 Crevalle jack	115	0.07	2.5
8 Dolphin	42	0.03	0.9
9 Greater amberjack	34	0.02	0.7
10 Gag	33	0.02	0.7
	4,447		97.5
Northwest Florida			
1 Blue runner	638	1.36	28.3
2 Little tunny	636	1.35	28.2
3 King mackerel	334	0.71	14.8
4 Dolphin	177	0.38	7.9
5 Atlantic bonito	164	0.35	7.3
6 Spanish mackerel	106	0.23	4.7
7 Unidentified porgies	31	0.07	1.4
8 Gray triggerfish	30	0.06	1.3
9.5 Greater amberjack	29	0.06	1.3
9.5 Wahoo	29	0.06	1.3
	2,174		96.5
Louisiana			
1 Dolphin	747	2.76	33.4
2 Spanish mackerel	572	2.11	25.6
3 Little tunny	346	1.28	15.5
4 King mackerel	248	0.92	11.1
5 Red drum	193	0.71	8.6
6 Blue runner	79	0.29	3.5
Louisiana cont.			
7 Yellowfin tuna	24	0.09	1.1
8 Wahoo	12	0.04	0.5
9.5 Blackfin tuna	4	0.01	0.2
9.5 Cobia	4	0.01	0.2
	2,229		99.7
South Texas			
1 Little tunny	1,005	1.17	60.8
2 King mackerel	155	0.18	9.4
3 Blackfin tuna	136	0.16	8.2
4 Dolphin	76	0.09	4.6
5 Blue runner	68	0.08	4.1
6 Yellowfin tuna	64	0.07	3.9
7 Atlantic bonito	29	0.03	1.8
8 Wahoo	26	0.03	1.6
9 Great barracuda	23	0.03	1.4
10 Skipjack tuna	22	0.03	1.3
	1,604		97.1

Table 9.—Ten most abundant species caught by trolling in each area off the southeastern United States and U.S. Caribbean during the 1985 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Dolphin	3,102	1.89	41.3
2 Yellowfin tuna	1,778	1.09	23.7
3 King mackerel	1,739	1.06	23.1
4 Spanish mackerel	294	0.18	3.9
5 Bluefish	178	0.11	2.4
6 Atlantic bonito	119	0.07	1.6
7 Wahoo	78	0.05	1.0
8 Greater amberjack	60	0.04	0.8
9 Great barracuda	43	0.03	0.6
10 Little tunny	40	0.02	0.5
	7,431		98.9
South Carolina			
1 King mackerel	619	1.11	48.5
2 Spanish mackerel	166	0.30	13.0
3 Great barracuda	99	0.18	7.8
4 Little tunny	98	0.18	7.7
5 Dolphin	83	0.15	6.5
6 Yellowfin tuna	64	0.11	5.0
7 Atlantic bonito	49	0.09	3.8
8 Greater amberjack	40	0.07	3.1
9 Wahoo	31	0.06	2.4
10 Gray triggerfish	10	0.02	0.8
	1,259		98.6
Georgia			
1 Spanish mackerel	184	0.98	25.4
2 King mackerel	179	0.95	24.7
3 Great barracuda	167	0.89	23.1
4 Little tunny	66	0.35	9.1
5 Crevalle jack	45	0.24	6.2
6 Black sea bass	18	0.10	2.5
7.5 Dolphin	17	0.09	2.3
7.5 Ladyfish	17	0.09	2.3
Georgia cont.			
9 Greater amberjack	15	0.08	2.1
10 Bluefish	12	0.06	1.7
	720		99.4
Northeast Florida			
1 King mackerel	301	0.56	22.7
2 Greater amberjack	248	0.46	18.7
3 Great barracuda	211	0.39	15.9
4 Spanish mackerel	173	0.32	13.1
5 Bluefish	126	0.24	9.5
6 Silver seatrout	60	0.11	4.5
7 Kingfishes	40	0.07	3.0
8 Dolphin	38	0.07	2.9
9 Leatherjacket	26	0.05	2.0
10 Wahoo	23	0.04	1.7
	1,246		94.0
East Florida			
1 Blue runner	1,166	0.72	23.0
2 Little tunny	1,054	0.65	20.8
3 King mackerel	956	0.59	18.9
4 Dolphin	704	0.43	13.9
5 Great barracuda	551	0.34	10.9
6 Atlantic bonito	236	0.14	4.7
7 Spanish mackerel	88	0.05	1.7
8 Sailfish	87	0.05	1.7
9 Bluefish	84	0.05	1.7
10 Wahoo	42	0.03	0.8
	4,968		98.1
Southeast Florida			
1 Atlantic bonito	278	0.21	22.2
2 King mackerel	229	0.17	18.3
3 Dolphin	213	0.16	17.0
Southeast Florida cont.			
4 Great barracuda	155	0.12	12.4
5 Blue runner	88	0.07	7.0
6 Sailfish	45	0.03	3.6
7 Bluefish	33	0.02	2.6
8 Greater amberjack	32	0.02	2.6
9 Little tunny	30	0.02	2.4
10 Hammerhead shark	25	0.02	2.0
	1,128		90.1
South Florida			
1 Dolphin	3,033	1.41	43.7
2 Great barracuda	781	0.36	11.2
3 King mackerel	632	0.29	9.1
4 Blackfin tuna	403	0.19	5.8
5 Black grouper	358	0.17	5.2
6 Cero	311	0.14	4.5
7 Atlantic bonito	251	0.12	3.6
8 Yellowtail snapper	211	0.10	3.0
9 Blue runner	153	0.07	2.2
10 Little tunny	115	0.05	1.7
	6,248		90.0
U.S. Caribbean			
1 Little tunny	492	0.13	25.6
2 King mackerel	359	0.10	18.6
3 Great barracuda	280	0.08	14.5
4 Dolphin	266	0.07	13.8
5 Yellowfin tuna	124	0.03	6.4
6 Cero	107	0.03	5.6
7 Wahoo	104	0.03	5.4
8 Blue marlin	61	0.02	3.2
9 Blackfin tuna	39	0.01	2.0
10 Sailfish	17	0.00	0.9
	1,849		96.0

Table 10.—Ten most abundant species caught by trolling in each area of the Gulf of Mexico during the 1985 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Spanish mackerel	63	1.75	36.6
2 Ladyfish	54	1.50	31.4
3 Bluefish	50	1.39	29.1
4 Crevalle jack	5	0.14	2.9
	172		100.0
West Florida			
1 Spanish mackerel	1,234	1.15	36.3
2 Little tunny	564	0.53	16.6
3 King mackerel	408	0.38	12.0
4 Great barracuda	336	0.31	9.9
5 Atlantic bonito	165	0.15	4.9
6 Blue runner	156	0.15	4.6
7 Dolphin	127	0.12	3.7
8 Crevalle jack	99	0.09	2.9
9 Unidentified lizard fishes	80	0.07	2.4
10 Greater amberjack	71	0.07	2.1
	3,240		95.4
Northwest Florida			
1 Spanish mackerel	546	1.52	33.1
2 Blue runner	443	1.23	26.9
3 King mackerel	159	0.44	9.6
4 Greater amberjack	154	0.43	9.3
5 Dolphin	100	0.28	6.1
6 Atlantic bonito	75	0.21	4.6
7 Bluefish	45	0.13	2.7
8 Skipjack tuna	32	0.09	1.9
9 Gag	24	0.07	1.5
10 Ladyfish	23	0.06	1.4
	1,601		97.1
Alabama			
1 Spanish mackerel	430	0.74	31.0
2 Little tunny	374	0.64	26.9
3 King mackerel	329	0.56	23.7
4 Atlantic bonito	69	0.12	5.0
5 Blue runner	61	0.10	4.4
6 Dolphin	39	0.07	2.8
7 Ladyfish	18	0.03	1.3
8 Crevalle jack	16	0.03	1.2
9 Cobia	11	0.02	0.8
11 Bluefish	10	0.02	0.7
11 Greater amberjack	10	0.02	0.7
11 Yellowfin tuna	10	0.02	0.7
	1,377		99.2
Mississippi			
1 Spanish mackerel	4,217	5.94	73.1
2 Atlantic bonito	424	0.61	7.5
3 King mackerel	249	0.35	4.3
4 Red drum	224	0.32	3.9
5 Blue runner	210	0.30	3.6
6 Crevalle jack	203	0.29	3.5
7 Ladyfish	70	0.10	1.2
8 Bluefish	57	0.08	1.0
9 Little tunny	43	0.06	0.7
10 Blacktip shark	28	0.04	0.5
	5,735		99.3
Louisiana			
1 Spanish mackerel	4,224	9.04	70.4
2 Little tunny	734	1.57	12.2
3 King mackerel	391	0.84	6.5
4 Red drum	246	0.53	4.1
5 Blue runner	183	0.39	3.0
Louisiana cont.			
6 Crevalle jack	132	0.28	2.2
7 Dolphin	26	0.06	0.4
8 Blackfin tuna	21	0.04	0.3
9 Wahoo	18	0.04	0.3
10 Yellowfin tuna	14	0.03	0.2
	5,989		99.6
North Texas			
1 Dolphin	1,969	2.52	36.9
2 King mackerel	1,135	1.45	21.3
3 Red snapper	732	0.94	13.7
4 Atlantic bonito	556	0.71	10.4
5 Bluefish	208	0.27	3.9
6 Spanish mackerel	175	0.22	3.3
7 Unidentified sharks	136	0.17	2.5
8 Blue runner	84	0.11	1.6
9 Crevalle jack	67	0.09	1.3
10 Greater amberjack	49	0.06	0.9
	5,111		95.8
South Texas			
1 King mackerel	1,498	1.07	40.5
2 Little tunny	801	0.57	21.6
3 Dolphin	249	0.18	6.7
4 Crevalle jack	183	0.13	4.9
5 Blue runner	173	0.12	4.7
6 Atlantic bonito	168	0.12	4.5
7 Atlantic sharpnose shark	142	0.10	3.8
8 Unidentified sharks	129	0.09	3.5
9 Greater amberjack	112	0.08	3.0
10 Blackfin tuna	43	0.03	1.2
	3,498		94.4

Table 11.—Ten most abundant species caught by other fishing in each area off the southeastern United States during the 1984 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Black sea bass	6,344	65.74	91.5
2 Unidentified porgies	417	4.32	6.0
3 Unidentified sand perches	56	0.58	0.8
4 Unidentified grunts	27	0.28	0.4
5 Red snapper	19	0.20	0.3
6 King mackerel	16	0.17	0.2
7 Spottail pinfish	11	0.11	0.2
8.5 Albacore	8	0.08	0.1
8.5 Gag	8	0.08	0.1
10 Gray triggerfish	7	0.07	0.1
	6,913		99.7
East Florida			
1 Black sea bass	942	2.51	29.8
2 Vermillion snapper	525	1.40	16.6
3 Red snapper	299	0.80	9.4
4 Unidentified grunts	285	0.76	9.0
East Florida cont.			
5 Greater amberjack	229	0.61	7.2
6 Snowy grouper	125	0.33	3.9
7 Gray triggerfish	89	0.24	2.8
8.5 Scamp	76	0.20	2.4
8.5 Spotted seatrout	76	0.20	2.4
10 Unidentified tilefishes	75	0.20	2.4
	2,721		85.9
Southeast Florida			
1 Unidentified snappers	108	0.61	29.9
2 Vermillion snapper	41	0.23	11.4
3 Unidentified tilefishes	39	0.22	10.8
4.5 Almaco jack	32	0.18	8.9
4.5 Greater amberjack	32	0.18	8.9
6 Snowy grouper	29	0.16	8.0
7 Hammerhead shark	12	0.07	3.3
8 Gray triggerfish	11	0.06	3.0
Southeast Florida cont.			
9 Dusky shark	9	0.05	2.5
10 Blue runner	8	0.05	2.2
	321		88.9
South Florida			
1 King mackerel	590	1.90	57.7
2 Yellowtail snapper	133	0.43	13.0
3 Unidentified grunts	52	0.17	5.1
4 Unidentified porgies	29	0.09	2.8
5 Red grouper	26	0.08	2.5
6 Gray snapper	24	0.08	2.3
7 Mutton snapper	22	0.07	2.2
8.5 Black grouper	19	0.06	1.9
8.5 Blue runner	19	0.06	1.9
10 Cero	18	0.06	1.8
	932		91.2

Table 12.—Ten most abundant species caught by other fishing in each area of the Gulf of Mexico during the 1984 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Gag	1,100	0.79	10.7
2 Spotted seatrout	1,064	0.76	10.3
3 Unidentified seatrouts	916	0.66	8.9
4 Ladyfish	850	0.61	8.3
5 Sheepshead	818	0.59	8.0
6 Red grouper	810	0.58	7.9
7 Gray snapper	774	0.55	7.5
8 Unidentified grunts	612	0.44	6.0
9 Silver perch	528	0.38	5.1
10 Greater amberjack	510	0.37	5.0
	7,982		77.7
West Florida			
1 Black sea bass	1,137	1.05	20.7
2 Spotted seatrout	902	0.83	16.4
3 Gray snapper	583	0.54	10.6
4 Gag	524	0.48	9.5
5 Unidentified grunts	447	0.41	8.1
6 Sheepshead	389	0.36	7.1
7 Silver seatrout	362	0.33	6.6
8 Red drum	274	0.25	5.0
West Florida cont.			
9 Ladyfish	210	0.19	3.8
10 Red grouper	190	0.17	3.5
	5,018		91.3
Northwest Florida			
1 Gray triggerfish	1,621	1.54	18.0
2 Red snapper	1,559	1.48	17.3
3 Unidentified porgies	1,379	1.31	15.3
4 Greater amberjack	1,262	1.20	14.0
5 Gag	778	0.74	8.6
6 Little tunny	546	0.52	6.1
7 Blue runner	506	0.48	5.6
8 Dolphin	252	0.24	2.8
9 Scamp	198	0.19	2.2
10 King mackerel	185	0.18	2.1
	8,286		92.0
Louisiana			
1 Sand seatrout	55,334	23.45	48.8
2 Atlantic croaker	29,220	12.38	25.8
3 Red snapper	10,836	4.59	9.6
Louisiana cont.			
4 Unidentified seatrouts	7,475	3.17	6.6
5 Red drum	2,258	0.96	2.0
6 Blue fish	2,200	0.93	1.9
7 Dolphin	1,465	0.62	1.3
8 Gray triggerfish	1,330	0.56	1.2
9 King mackerel	993	0.42	0.9
10 Greater amberjack	948	0.40	0.8
	112,059		98.9
South Texas			
1 Red snapper	1,706	1.30	25.4
2 King mackerel	1,675	1.28	24.9
3 Silver seatrout	870	0.66	12.9
4 Crevalle jack	729	0.56	10.8
5 Atlantic spadefish	482	0.37	7.2
6 Atlantic bonito	277	0.21	4.1
7 Atlantic sharpnose shark	268	0.20	4.0
8 Gray triggerfish	114	0.09	1.7
9 Red drum	92	0.07	1.4
10 Blacktip shark	87	0.07	1.3
	6,300		93.7

During the 1984 survey, 199,836 fishes were caught. The trolling catch of 40,776 fishes, which represented 66 species or species groups, was made up mostly of coastal (88.8 percent) and oceanic (7.6 percent) pelagics (Table 3). Other fishing techniques produced 159,060 fishes, representing 108 species or species groups, of which 89.3 percent were demersal (Table 4).

In 1985, 142,419 fishes were caught. Troll-caught fishes numbered 54,090, which represented 82 species or species groups, of which 89.4 percent were coastal pelagic and 7.1 percent were oceanic pelagic (Table 5). Other fishing techniques caught 88,329 fishes, representing 102 species or species groups, of which 81.8 percent were demersal (Table 6).

The CPH of the top ten species varied by method and by area in both 1984 and 1985 (Tables 7-14). For both years, and in all areas, the importance of scombrids (tunas and mackerels) in trolling catches was apparent (Tables 7-10), while catches using other fishing techniques showed the importance of snappers (lutjanids), groupers (serranids), and croakers (sciaenids), (Tables 11-14).

Discussion and Summary

Aside from providing fishing information on what can be caught by recreational user groups in given locations, the data from charterboat surveys can be used to investigate variations and trends in seasonality and abundance of coastal pelagic and demersal fishes. For example, CPUE data are now available for five areas (North Carolina, south and northwest Florida, Louisiana, and south Texas) of the southeastern United States from 1982 through 1985. All 16 coastal areas now have at least two years of

Table 13.—Ten most abundant species caught by other fishing in each area off the southeastern United States during the 1985 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Black sea bass	3,473	41.10	97.6
2 Unidentified porgies	60	0.71	1.7
3 Gag	15	0.18	0.4
4 King mackerel	6	0.07	0.2
5 Crevalle jack	2	0.02	0.1
6 Cobia	1	0.01	0.0
	3,557		100.0
South Carolina			
1 Black sea bass	40	1.00	47.1
2 Greater amberjack	21	0.53	24.7
3 Blacktip shark	6	0.15	7.1
4.5 Great barracuda	4	0.10	4.7
4.5 Unidentified sharks	4	0.10	4.7
6.5 Atlantic spadefish	3	0.08	3.5
6.5 Bluefish	3	0.08	3.5
8 Hammerhead shark	2	0.05	2.4
9.5 King mackerel	1	0.03	1.2
9.5 Spanish mackerel	1	0.03	1.2
	85		100.1
Georgia			
1 Black sea bass	805	2.59	33.9
2 Vermillion snapper	570	1.84	24.0
3 Bluefish	215	0.69	9.1
4 Red snapper	159	0.51	6.7
5 Great barracuda	111	0.36	4.7
6 King mackerel	104	0.33	4.4
Georgia cont.			
7 Greater amberjack	85	0.27	3.6
8 Unidentified sharks	82	0.26	3.5
9 Ladyfish	43	0.14	1.8
10 Blacktip shark	36	0.12	1.5
	2,210		93.2
Northeast Florida			
1 Black sea bass	504	1.51	24.9
2 Unidentified seatrouts	366	1.10	18.1
3 Kingfish	353	1.06	17.4
4 Sheepshead	289	0.87	14.3
5 Bluefish	169	0.51	8.3
6 Red drum	89	0.27	4.4
7 Unidentified sharks	61	0.18	3.0
8 Unidentified flounders	34	0.10	1.7
9 Gray triggerfish	32	0.10	1.6
10 Red snapper	24	0.07	1.2
	1,921		94.9
East Florida			
1 Yellowtail snapper	788	1.53	16.7
2 Black sea bass	695	1.35	14.7
3 Unidentified grunts	630	1.22	13.3
4 Vermillion snapper	543	1.05	11.5
5 Blue runner	354	0.69	7.5
6 Red snapper	325	0.63	6.9
7 Gray triggerfish	298	0.58	6.3
8 Greater amberjack	242	0.47	5.1
East Florida cont.			
9 Atlantic sharpnose shark	86	0.17	1.8
10 Snowy grouper	72	0.14	1.5
	4,033		85.3
Southeast Florida			
1 Little tunny	104	0.20	24.9
2 Hammerhead shark	43	0.08	10.3
3 Spanish mackerel	41	0.08	9.8
4 Greater amberjack	39	0.08	9.3
5 Sailfish	34	0.07	8.1
6 Blue runner	28	0.05	6.7
7 Great barracuda	25	0.05	6.0
8 Dolphin	19	0.04	4.5
9 Unidentified snappers	16	0.03	3.8
10 Atlantic bonito	13	0.03	3.1
	362		86.5
South Florida			
1 Yellowtail snapper	1,190	1.79	30.0
2 Gray snapper	517	0.78	13.0
3 Mutton snapper	268	0.40	6.8
4 Blue runner	234	0.35	5.9
5 Greater amberjack	181	0.27	4.6
6 Little tunny	163	0.25	4.1
7.5 Crevalle jack	144	0.22	3.6
7.5 King mackerel	144	0.22	3.6
9 Vermillion snapper	81	0.12	2.0
10 Ladyfish	78	0.12	2.0
	3,000		75.6

Table 14.—Ten most abundant species caught by other fishing in each area of the Gulf of Mexico during the 1985 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Red grouper	2,382	1.46	19.0
2 Gray snapper	1,648	1.01	13.2
3 Spotted seatrout	1,159	0.71	9.3
4 Ladyfish	1,008	0.62	8.1
5 Gag	807	0.50	6.5
6 Sheepshead	805	0.49	6.4
7 Yellowtail snapper	760	0.47	6.1
8 Unidentified seatrouts	623	0.38	5.0
9 Greater amberjack	593	0.36	4.7
10 Lane snapper	350	0.21	2.8
	10,135		81.1
West Florida			
1 Gag	2,182	2.02	29.1
2 Black sea bass	1,983	1.83	26.4
3 Gray snapper	815	0.75	10.9
4 Red grouper	723	0.67	9.6
5 Unidentified grunts	573	0.53	7.6
6 Gray triggerfish	234	0.22	3.1
7 Unidentified porgies	148	0.14	2.0
8 Unidentified squirrelfishes	112	0.10	1.5
9 Greater amberjack	108	0.10	1.4
10 Yellowtail snapper	104	0.10	1.4
	6,982		93.0
Northwest Florida			
1 Gray triggerfish	3,076	2.09	21.4
2 Unidentified porgies	2,441	1.65	17.0
3 Gag	2,303	1.56	16.1
4 Greater amberjack	1,991	1.35	13.9
5 Red snapper	1,759	1.19	12.3
6 Vermillion snapper	1,364	0.92	9.5
7 Little tunny	334	0.23	2.3
8 Blue runner	271	0.18	1.9
Northwest Florida cont.			
9 Scamp	208	0.14	1.4
10 Dolphin	172	0.12	1.2
	13,919		97.0
Alabama			
1 Red snapper	1,623	3.56	46.1
2 Gray triggerfish	747	1.64	21.2
3 Gag	473	1.04	13.4
4 Vermillion snapper	324	0.71	9.2
5 Greater amberjack	95	0.21	2.7
6 Unidentified porgies	92	0.20	2.6
7 Unidentified grunts	44	0.10	1.2
8 Cobia	24	0.05	0.7
9 Red grouper	16	0.04	0.5
10 Scamp	13	0.03	0.4
	3,451		98.0
Mississippi			
1 Sand seatrout	887	2.84	31.2
2 Atlantic bonito	513	1.64	18.0
3 Red snapper	470	1.51	16.5
4 Spotted seatrout	296	0.95	10.4
5 Blacktip shark	196	0.63	6.9
6 Unidentified sharks	88	0.28	3.1
7 Crevalle jack	75	0.24	2.6
8 Red drum	62	0.20	2.2
9 Gray triggerfish	52	0.17	1.8
10 Bluefish	36	0.12	1.3
	2,675		94.0
Louisiana			
1 Sand seatrout	13,864	16.76	51.9
2 Atlantic croaker	5,608	6.78	21.0
3 Unidentified seatrouts	1,963	2.37	7.3
Louisiana cont.			
4 Red snapper	1,644	1.99	6.1
5 Yellowtail snapper	700	0.85	2.6
6 Red drum	547	0.66	2.0
7 Bluefish	528	0.64	2.0
8 Pinfish	474	0.57	1.8
9 Unidentified sharks	299	0.36	1.1
10 King mackerel	244	0.30	0.9
	25,871		96.7
North Texas			
1 Red snapper	1,551	5.07	58.1
2 Little tunny	212	0.69	7.9
3 King mackerel	153	0.50	5.7
4 Atlantic bonito	140	0.46	5.2
5 Greater amberjack	116	0.38	4.3
6 Gray triggerfish	112	0.37	4.2
7 Sand seatrout	96	0.31	3.6
8 Black sea bass	48	0.16	1.8
9 Bluefish	43	0.14	1.6
10 Atlantic sharpnose shark	37	0.12	1.4
	2,508		93.8
South Texas			
1 Red drum	344	1.20	45.6
2 Spotted seatrout	149	0.52	19.8
3 Red snapper	62	0.22	8.2
4 Ladyfish	33	0.12	4.4
5 Blacktip shark	29	0.10	3.8
6 Hardhead catfish	23	0.08	3.1
7 Pinfish	19	0.07	2.5
8 Unidentified flounders	17	0.06	2.3
9 Atlantic spadefish	14	0.05	1.9
10 Unidentified seatrouts	10	0.03	1.3
	700		92.9

CPUE information (Fig. 1). Similarly, annual variations in relative abundance of several species may be examined, such as king mackerel (Trent et al., 1987) and Spanish mackerel (Palko et al., 1987). However, geographic comparisons are not always possible for demersal species due to differences in distribution or occurrence (e.g., yellowtail snapper in south Florida, black sea bass on the Atlantic coast, red grouper in south and southwest Florida, and Atlantic croaker or sand seatrout in Louisiana). The latter, however, may be a function of target species, and may reflect fishermen preference within areas. Other limitations of survey data have been previously discussed by Brusher et al. (1984) and Brusher and Palko (1985).

In summary, the data from the 1982 through 1985 charterboat surveys provided information on catches and effort, which in turn permits examination of seasonal and geographic abundance of fishes caught by trolling and by other fishing methods.

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Nutritional Properties of Recreationally Caught Marine Fishes

MAURICE E. STANSBY

Introduction

This paper discusses the nutritional properties of various species of fish caught by marine anglers. Most of the species mentioned are strictly marine, although a few are anadromous. Actually, most recreationally caught fish are ones which also are caught and marketed by commercial fishermen; there is, of course, no difference in the nutritional properties whether the fish are caught by either means.

The terms oil and fat can be used interchangeably; here, we use the term oil. The oil content of fishes varies to a greater extent (from 0.3 to 15 percent or more) than any other component in fish flesh or even in meats. The moisture content of fish tends to vary inversely with the oil content, and the sum of the two items usually approximates 80 percent.

The protein content of fish usually ranges from 18 to 20 percent, but may be as low as 13 percent or as high as 26 percent for a few species. The ash content of fish flesh is about 1.25 percent, falling occasionally to 1 percent or a little less, or sometimes rising to 1.5 percent. If some fine bones or parts of bones have not been eliminated, as in some canned fish, the ash content may appear to be much higher.

Fish have been classified into five categories based on the relative percentages of protein and oil in the flesh (Stansby, 1962). These range from category A, low oil-high protein, to category E, low oil-low protein (Table 1).

For low calorie diets (as for weight reduction), species of fish in category A are especially desirable because they have a low calorie content (low oil—lower than most meats), but as high a protein content as other flesh foods. Category B corresponds to fish having composition comparable to meat (excepting, of course, the levels of the omega 3 and 6 fatty acids as discussed later in this paper). Fish in category D are especially valuable for individuals requiring high protein content since the protein in these species is at higher levels than in other flesh foods. Many, if not most of the species sought by marine anglers are in the desirable categories A, B, or D.

While there may be, on the average, considerable differences in nutritive value from one species of fish to another, there may be also a large difference in nutritional properties of fish of the same species when the fish are taken from different waters or at different seasons of the year. This is due in part to changing food availability or feeding patterns, changes due to spawning conditions and migrations, and other factors.

Fish Composition Compared With Other Flesh Foods

Protein

The amount of protein in fish flesh (usually about 18-20 percent for most species) is ordinarily about the same as that of the flesh of meat and poultry. Occasionally the amount of protein in fish flesh may be as high as 22 percent or a little more. On the other hand, there are a very few species of fish where the protein content is as low as 14 percent, and even more rarely, slightly less. Thus, the protein content is relatively constant in fish, and the variation between the lowest and highest protein content is never more than two times. The quality of the protein of fish, as measured by its amino acid content, is almost identical to that of the

Maurice E. Stansby is a scientific consultant with the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Table 1.—Types of fish and representative species (Stansby, 1962)

Category	Type of fish	Species	Moisture	Protein	Oil	Ash
A	Low oil-high protein (<5%) (15-20%)	Pacific cod, *Gadus macrocephalus*	81.5%	17.9%	0.6%	1.6 %
B	Medium oil-high protein (5-15%) (15-20%)	Mackerel, *Scomber scombrus*	67.5%	18 %	13 %	1.5 %
C	High oil-low protein (>15%) (<15%)	Lake trout, *Salvelinus namaycush siscowet*	52.5%	11.3%	36.0%	0.53%
D	Low oil-very high protein (<5%) (>20%)	Skipjack tuna, *Katsuwonus pelamis*[1]	72.4%	26.2%	0.7%	1.5 %
E	Low oil-low protein (<5%) (<15%)	Butter clam, *Saxidomus nuttall*	83.0%	13.3%	1.3%	1.9 %

[1]Light meat only.

protein in other flesh foods such as meat and poultry.

Fish Oils

The oil content of fish, unlike the protein content, is, on average, considerably less than that of meat. Furthermore, the oil content of fish flesh varies a great deal from one species to another, or even between samples of a given species. The average oil content among most fish is usually between 1 and 13 percent (Stansby, 1986), a thirteenfold variation. On the other hand if we consider the variation from fish to fish instead of on average values for the different species, then a huge variation of from about 0.3 to 65 percent can occur. This is a variation of about 200 times. There is no comparable variation in fat content for the flesh of meat or poultry, where variations are seldom more than eightfold.

Most species of fish—even those considered to have a higher range of oil content—are on the average lower in fat than most meat samples. If one is attempting to select a fish of a given oil content, one also has to take into account both the species of fish and often either season of the year when the fish was caught or sometimes also the geographical area where the fish was taken. These variations in fat content of fish of the same species relate to 1) the spawning season, whereby as the season advances the oil content may build up to several times as high as it was at the beginning and then drop sometimes rapidly to a low level after spawning, or 2) to the fact that the oil content of fish depends in part upon the kind and amount of feed available to it, and the feed in the water often varies extensively from one geographical area to another. This latter factor results in a much wider variation in fat content of fish than is the case with domestic animals where the type of feed is more nearly constant.

The type or composition of oil in fishes is also different than that in meat. The type of fat is usually a function of the particular fatty acids combined together as triglycerides or phospholipids. Most animal fats (as well as vegetable oils) contain fatty acids of chain lengths of 16-18 carbons atoms (predominantly 16 and 18). Each fatty acid in animal fats usually contains from 0 to 4 (usually from 0 to 2) double bonds.

Fish oils, on the other hand, while containing most of the same fatty acids in meat fats, also contain substantial quantities of longer chain length (C20 and C22) fatty acids. Furthermore, fish oils contain considerable amounts of fatty acids with 5 and 6 double bonds making them highly polyunsaturated. In fatty acids from meat, the polyunsaturation is largely made up from fatty acids with 2 double bonds, and although trace or very small quantities with 3 or 4 double bonds may occur, there never are any with 5 or 6 double bonds.

Of perhaps even greater importance from a nutritional standpoint is the fact that the arrangement of the double bonds in the long-chain fatty acids of fish oils is generally quite different from that in the fatty acids of meat fats. In fats other than marine oils, any long chain (over C18) polyunsaturate that may be present has its first double bond at the sixth carbon atom from the methyl end. When the fatty acids are numbered from the methyl end, the position of the double bond is designated as the omega position. Thus all long-chain polyunsaturates of oils or fats of flesh foods other than those from fish, are called omega-6 (N-6) fatty acids. With fish oils, however, most of the long-chain polyunsaturated fatty acids have their first double bond starting at the third carbon atom and are therefore designated as omega-3 (N-3) fatty acids. As will be seen in a subsequent section the omega-3 fatty acids can possess desirable nutritional properties not present in the omega-6 variety.

Other Components

The principal component of fish is moisture (water) which usually amounts to 65-80 percent, but which does not contribute to nutritional value. As mentioned, water content tends to vary inversely with oil content. Several other components, present in relatively small quantities, can have important nutritional value. All flesh foods contain inorganic material, which, when proximate composition of the food is determined, are lumped together and termed "ash content". These are determined by heating the food to such a high temperature that all organic material is volatilized along with the moisture. The remaining inorganic materials occur after the heating in the form of oxides of the metallic cations of the inorganic substances.

Ordinarily the "ash" amounts to about 1.2 percent or just a little more in flesh foods. The ash mostly comes from such compounds as sodium and potassium salts. Some nutritionally important elements, such as calcium also occur. In fish, the amount of calcium often exceeds that occurring in other flesh foods. This is particularly the case where fish bone remains in canned fish; then the calcium content can be especially high. Other inorganic components occurring in very small quantities are known as trace elements. Fish contains considerably higher quantities of the trace element iodine, which is also important nutritionally.

All flesh foods contain vitamins, particularly the various B complex vitamins such as thiamine, riboflavin, and vitamin B_{12}. The amounts of these vitamins are similar in the various flesh foods including fish. Vitamins A and D occur to a fairly high level in the fat of fish. These amounts are higher in fatty fish than in leaner ones, or in the fat of other flesh foods. Vitamin A occurs in the form of carotene in many vegetables, such as carrots, to a much higher level than the vitamin A in fish, however.

Fatty Acid Stability During Fish Storage

Because fish oil fatty acids contain 5 and 6 double bonds compared with mostly 2 or 3 in those of other flesh foods or oils, the fish oil fatty acids oxidize and deteriorate more rapidly than is the case with the oils or fats in other foods. The only way to eliminate all such oxidation is to keep the fish or its oil away from all air. Ordinarily this is usually not possible, but any protective barrier which reduces penetration of oxygen from the air into the fish (such as wrapping in moisture-proof paper) reduces on the speed of oxidation.

The oils from fish of different species vary in their content of the long-chain polyunsaturated fatty acids, and thus oils from some species are much more vulnerable to oxidation than those from others. Unfortunately we have very little information on the content of the fatty acids

most highly susceptible to oxidation in fish of different species. Until research provides such data we should treat all fish or fish oils in a way to minimize their contact with oxygen.

Ordinarily, fish oils oxidize relatively slowly when they are in the raw flesh of fish which are kept cold, such as by being held in ice. Once the fish are cooked, however, oxidation, with development of obnoxious rancid flavors, can be quite rapid. Frozen fish, unless glazed by dipping in water while frozen to form an ice coating, will oxidize appreciably with both formation of rancid flavors and eventually the loss of some of the long-chain omega-3 fatty acids after prolonged storage. These changes occur more rapidly when the fat of a given species of fish contains more of these long-chain polyunsaturated fatty acids. For example, pink salmon (which has very high amounts of such vulnerable fatty acids) after freezing and storage can become rancid after only a few weeks in storage. Some other salmon species such as king salmon, with less of these polyunsaturates, can be kept for many months after freezing without developing objectionable flavors if wrapped in moisture or vapor-proof wrappers. If they are given an ice glaze before wrapping they may remain palatable for more than a year.

When fish are cooked, the use of high temperatures during the cooking process will also favor oxidation of the fish oils to produce undesirable flavors and loss of the valuable omega-3 fatty acids. Use of relatively low temperatures such as boiling in water or even by baking or broiling gives much less such chance for oxidation than by frying.

Some Aspects of Fat in Fish and Nutritional Value

Low Fat Fish for Weight Reduction

Fish can play two special roles in the diet when used more frequently. For overweight individuals who want to reduce, use of the least oily species of fish can considerably reduce the calories consumed while providing high-quality protein and other nutritional components. A number of species of fish contain well under 1 percent fat which is in marked contrast to lean meats or other flesh foods where there is seldom less than 10 percent fat.

Marine fishes with less than 1 percent fat include haddock, cod, and pollock. (Most all shellfishes and crustaceans also contain only about 1 percent oil.) Use of such species drastically reduces one's fat intake compared with the consumption of flesh foods other than fish. Furthermore, there are many species of fish which have a fat content of from 1 to about 3.5 percent. These include, for example, most flatfishes (i.e., flounder, sole, and halibut), as well as ocean perch, Pacific ocean perch, mullet, and many others. Fresh (i.e., uncanned) tuna or tuna canned in brine (rather than oil) also has a very low fat content. Thus, for those seeking weight reduction, catching and eating fishes of very low fat content can provide a nutritious food with far fewer calories than meat.

Fish as a Source of Omega-3 Fatty Acids

As mentioned, fish are unique among all foods in having an abundant supply of long-chain omega-3 fatty acids in their oil. Much recent research indicates that consumption of such fatty acids has a beneficial effect in lessening the risk of heart attack and, in some cases, perhaps other medical conditions (Lands and Bimbo, 1983; Lands, 1986, Stansby, 1985). Dozens of research papers have been published in the past several years on this subject (e.g., see Simopoulos et al., 1986).

For individuals who want to increase their intake of long-chain omega-3 fatty acids, the best way at present is to consume species of fish having a moderately high fish oil content (about 5-10 percent). Such species have no more oil than occurs in even the leanest varieties of meat (which of course contains no omega-3 fatty acids). Such marine species of fish would include, for example, salmon (all species), herring, sardines, sablefish, mackerel, and many others. Other species of fish with lower fat content would furnish smaller, but still important, amounts of omega-3 fatty acids.

One problem in seeking species of fish having adequate amounts of omega-3 fatty acids is the lack of reliable data on the omega-3 fatty acid content (Stansby, 1981). A number of tables giving such values have been published recently but they are all based upon data involving inadequate sample sizes. Recently published values for omega-3 fatty acids in oil from different species of fish are therefore apt to be quite erroneous. It is better (and easier) to use the overall fat content of fish as an approximate index of omega-3 fatty acids. As pointed out by Stansby (1986), the availability of omega-3 fatty acids in fish is, to a large extent, a function of the oil content of the fish. While there is a small (but indeterminate under the present lack of knowledge) variation in the omega-3 fatty acid content, there is a very large variation in fat content.

Composition of Recreationally Caught Marine Fishes

As noted, the composition and nutritive value of marine fish is the same, whether caught commercially or recreationally. Table 2 shows the proximate compositions of selected species of fish which are taken in various parts of the country by recreational fishermen.

In choosing species for inclusion in Table 2, preference was usually given to species especially sought by marine recreational fishermen. Some species are strictly marine, but some are anadromous, returning to freshwater to spawn.

Information on what are considered desirable sport fishes was found in some tabulations on the catches of recreational fishermen. For example, in the publication Marine Recreational Fishery Statistics Survey, Atlantic and Gulf Coast, 1985 (NMFS 1986), Table 34, "Fish species sought out by fishermen" lists bluefish as most sought by marine anglers in the north and middle Atlantic areas; spotted seatrout is listed first in the south Atlantic and Gulf areas. Since composition data for each of these species were available they were included in Table 2.

There is no trend apparent or implied in the information in Table 2. High-oil and low-oil content species of fish are listed, as are fish with protein content varying from 17 to 22 percent (17 percent is a low value and 22 percent is a high value).

Table 2.—Proximate composition of 25 species of fish taken by marine anglers.

Common name	Scientific name	Where[1] caught	Moisture	Protein	Oil (range)	Oil (avg.)	Ash	Data source
Albacore (light meat)	*Thunnus alalunga*	P	66.4	25.9	0.5-18	8.1	1.25	Unpubl.[2]
Striped bass	*Morone saxatilis*	A, P[3]	77	19	n.d.[4]	2.8	1.1	Atwater (1892)
Bluefish	*Pomatomus saltatrix*	A	72	20	0.6-20	7	1.1	Gooch et al. (1987)
Atlantic cod	*Gadus morhua*	A	81.4	17.4	0.1-0.6	0.30	1.25	Atwater (1892)
Pacific cod	*Gadus macrocephalus*	P	81.4	16.0	0.5-0.8	0.63	1.20	Unpubl.[2]
Spiny dogfish	*Squalus acanthias*	A, P	71.1	15.4	5-20	13.2	1.20	Unpubl.[2]
Red drum	*Sciaenops ocellatus*	A	79	19	0.6-1.1	0.9	1.0	Gooch et al. (1987)
Haddock	*Melanogrammus aeglefinnus*	A	81.7	17.2	n.d.[4]	0.25	1.23	Atwater (1892)
Pacific halibut	*Hippoglossus stenolepis*	P	80	18.5	n.d.[4]	0.8	1.1	Unpubl.[2]
King mackerel	*Scomberomorus cavalla*	A	76	21	0.8-3.0	1.7	1.4	Gooch et al. (1987)
Pollock	*Pollachius virens*	A	80.3	18.6	n.d.[4]	0.6	1.16	Unpubl.[2]
Walleye (Alaska) pollock	*Theragra chalcogramma*	P	81.2	16.7	0.2-2.0	0.8	1.4	Unpubl.[2]
Longspine porgy	*Stenotomus caprinus*	A	80	18	1.3-1.6	1.5	1.0	Gooch et al. (1987)
Rockfishes	*Sebastes* spp.	P	78	19	0.6-4.1	1.5	1.2	Thurston (1961)
Coho salmon	*Oncorhynchus kisutch*	P[3]	69	21	5.2-12.5	8.3	1.2	Karrick and Thurston (1964)
Sockeye salmon	*Oncorhynchus nerka*	P[3]	68	22	5.1-10.6	8.9	1.1	Thurston and Newman (1962)
White seabass	*Cynoscion nobilis*	P	80.5	17.4	n.d.[4]	0.8	1.1	Unpubl.[2]
Spotted seatrout	*Cynoscion nebulosus*	A	77	19	1.6-3.7	2.6	1.1	Gooch et al. (1987)
Tiger shark	*Galeocerdo cuvieri*	A	80	19.2	0.6-0.7	0.6	1.2	Gooch et al. (1987)
Spot	*Leiostomus xanthurus*	A	75	18	4-7	6.0	1.1	Gooch et al. (1987)
Swordfish	*Xiphias gladius*	A, P	76	19.9	n.d.[4]	3.7	1.3	Gooch et al. (1987)
Steelhead (rainbow) trout	*Salmo gairdneri*	P[3]	68	21.2	6-16	9.5	1.3	Unpubl.[2]
Bluefin Tuna (light meat)	*Thunnus thynnus*	A, P	70.3	24.2	2-7	5.7	1.3	Unpubl.[2]
Yellowfin tuna	*Thunnus albacares*	P	70.3	24.6	0.5-4	1.3	1.6	Unpubl.[2]
Weakfish	*Cynoscion regalis*	A	78	19	1.0-2.6	1.7	1.1	Gooch et al. (1987)

[1]A = Atlantic and/or Gulf waters, P = Pacific.
[2]Unpublished data from files of Utilization Research Division, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash.
[3]Also is anadromous and may be taken by freshwater anglers.
[4]Too few data to show ranges or based on data from very few samples.

There are a very large number of species of recreational fish not included in Table 2 for it is beyond the scope of this report to list many dozens of species. Those included cover species caught in the Atlantic and Pacific Oceans and several anadromous species taken in fresh waters. The values can be considered as typical for recreationally caught marine fishes.

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Encouraging the Use of Underutilized Marine Fishes by Southeastern U.S. Anglers, Part I: The Research

JEFFREY C. JOHNSON, DAVID C. GRIFFITH, and JAMES D. MURRAY

Introduction

Every year, millions of fishermen discard, release, or unnecessarily ruin and waste millions of pounds of saltwater fish that they consider poor eating or inedible. The National Marine Fisheries Service (NMFS) estimates that, from the Atlantic and Gulf coasts alone, recreational fishermen catch over 33 million fish belonging to such underutilized groups such as jacks, catfishes, tunas, and skates and rays (USDOC, 1980). Most of these fish are discarded or released in favor of more highly desired and perhaps overfished species like grouper, snapper, and king mackerel (Bell, et al. 1982). This underutilization of potentially valuable marine resources occurs at a time: 1) When increased real and perceived pressure is being placed on preferred marine resources by both recreational and commercial fishermen, both of whom use increasingly more efficient technologies to locate and catch fish; and 2) with political conflicts between marine recreational fishermen and commercial fishermen over access to and claim over marine resources (Berkes, 1984). Presumably, increasing the share of underutilized species in the total recreational catch will aid in reducing both biological pressures and subsequent political conflicts.

In 1983, we began investigating southeastern U.S. marine recreational fishermen's beliefs about species of saltwater fish in an attempt to isolate the specific criteria upon which they base their decisions to use or reject a fish. This was part of a 3-year program to increase demand for underutilized species among marine recreational fishermen of the U.S. southeast. During the first year we empirically investigated fishermen's perceptions concerning fish and developed informant-based models, which forms the core of this paper. Based on this earlier research, we have subsequently attempted to enhance the images or to "repackage" underutilized species with an educational program consisting of brochures, posters, recipes, and a slide/tape presentation.

In this paper, Part I, we present a brief description of the research and its findings, focusing on the implications of this work in the development of the educational program. The philosophy, dynamics, and achievements of the educational program are the focus of Part II (Murray et al., 1987).

ABSTRACT—Ths paper is the first of a two-part series which describes and discusses the integration of research and extension increase to the use of nontraditional fishes among marine recreational fishermen in the southeastern United States. Recreational fishermen within this region target and use or reject fish on the basis of a variety of criteria. Many fish caught incidentally are discarded because of myth, rumor, or perceived negative characteristics that mask the species' positive values. To discover the factors influencing the angler's evaluations concerning the desirability of fish that ultimately affects their decision to accept or reject a particular species, we collected judged-similarity and belief-frame comparison data in Florida, North Carolina, and Texas, analyzing these data with the use of multidimensional scaling, hierarchical clustering, and entailment analysis. We briefly describe the use of these procedures in providing for a systematic understanding of fishermen's perceptions concerning fish and discuss the implications of our findings for the development of educational materials directed at enhancing the image of certain underutilized species among marine recreational fishermen.

Methods

Data Collection and Analysis

In exploring the perceptions that recreational fishermen have of various marine species, we incorporated methods and theories from the fields of anthropology and consumer research. Two techniques we used are multidimensional scaling (MDS) (Kruskal, 1964) and hierarchical clustering (HCL) (Johnson, 1967). Generally, any items that can be compared on the basis of similarity or dissimilarity can be visually represented as points spatially distributed in euclidean space (MDS) or as items grouped together hierarchically as a taxonomic structure (HCL). Both techniques display relationships among items or stimuli (e.g., different kinds of fish) based on measures of similarity/dissimilarity (a more detailed discussion is given by Romney et al., 1972).

Jeffrey C. Johnson is Associate Scientist and David C. Griffith is Assistant Scientist with the Institute for Coastal and Marine Resources, East Carolina University, Greenville, NC 27858-4353. James D. Murray is Director, Marine Advisory Services, UNC Sea Grant College Program, North Carolina State University, Raleigh, NC 27695. This research was funded by the National Marine Fisheries Service, NOAA, under the Saltonstall-Kennedy Program Contract No. NA83-WC-H-0016. Portions of this paper were derived from Johnson and Griffith (1985) and Johnson et al. (1986).

We used these techniques to explore fishermen's judged similarities between selected saltwater fishes. To accomplish this, we asked fishermen to sort cards with pictures and names of fish on them into piles on the basis of how they perceived species to be similar to one another. We then asked them to explain their groupings. Consequently, the common group memberships among species, the relationships among the groups, and the derived similarity measures between the species were determined by the manner in which fishermen sorted species into piles.

Two methods for deriving similarity data from the pile sorts were explored. The first is based on information theory and tends to emphasize minor distinctions made by subjects (Burton, 1972). The second is based on the summing of co-occurrence of items (stimuli) in a pile across all subjects (Weller, 1984). Comparisons and tests of both techniques convinced us that, for our purposes, the latter provided a better measure of similarity for use with these statistical procedures.

The information derived from these methods is necessary to first identify relationships among saltwater species as perceived by recreational fishermen, and to determine the characteristics which make saltwater species desirable or undesirable. Discovering the relative position of underutilized species within a multidimensional scaling's configuration of points is analogous to the concept of "product positioning" in marketing research.

The concept of "product positioning" refers to the discovery of the structure of a particular product domain (e.g., different kinds of coffee) and the development and packaging of new products or old ones for new markets based on identification of yet unexploited portions of this particular domain. A good example of this is the development of a new popular brand of coffee with the use of the above methods (Stefflre, 1972).

We used one further method to identify and understand the ways recreational fishermen think about their prey. This involved constructing sentence frames (belief-frames) based on interviews with recreational fishermen from each study area. Recurring descriptions of both traditional and nontraditional recreational species (e.g., fighting characteristics, eating characteristics, etc.) were used to produce fill-in-the-blank sentences. In subsequent interviews, subjects were asked to provide the species (from an appropriate list) associated with the attribute implied in each sentence, such as "You cannot eat _____ because it has worms."

These species/belief-frame comparisons were incorporated into an "item-by-use" matrix (Stefflre, 1972) organized in a species-by-attribute form for each of the study areas. This is similar to a method used in the study of food snacks and their attributes with respect to when they are eaten (Stefflre, 1972). Each species/belief-frame matrix was sorted by rows and columns so that rows that were similar to one another were near one another; and columns that were similar to one another were near one another. This was accomplished through a combination of techniques used by both D'Andrade et al. (1972) and Stefflre (1972). D'Andrade et al. (1972) computed Pearson correlations for belief-frames across items and for items across belief-frames. These coefficients represented similarity measures and were clustered for rows and columns through the use of a hierarchical clustering scheme (Johnson, 1967).

Stefflre (1972), on the other hand, produced a similarity measure based on row-row and column-column similarity in patterning. For our purposes, however, we use a computationally equivalent algorithm which alleviates the need for transposing row and column vectors. These similarities were then used in an iterative process based on "linear equivalence chains" to sort rows and columns on the basis of similarity (Stefflre, 1972).

In this analysis, row-row and column-column similarities were derived with the use of the computationally equivalent version of Stefflre's algorithm discussed above. These similarity measures for both rows and columns were subjected to HCL to obtain the sorted species/belief-frame matrices for each region.

Data from the belief-frame comparisons can also be modeled in terms of implicational or logical relationships (D'Andrade, 1976; Schoepfle et al., 1984; White et al., 1977; White and McCann[1]). The structure of these relationships, or the entailment structure, is obtained through a multivariate contingency analysis of paired dichotomous variables similar to Guttman scaling. The logical or implicational relations are modeled in an "If A then B" (visualized in Figures 10-13 as A<--------B) form and are not symmetrical. It allows for both complete and partial orderings in which relationships are transitive. Two other forms are possible. The first is the equivalence relation, which takes the symmetrical form of "A = B" and the contrast relation of the form "If A then not B." A more detailed description can be found in D'Andrade (1976) and White et al. (1977).

Sampling

An important consideration for the application of these techniques is the assumption that there are shared understandings, beliefs, or pools of information among respondents and the cultures or subcultures of which they are a part, in the same way that a handful of English speakers can provide a complete grammar of English. For example, a review of studies that employed MDS interviewed between 10 and 50 subjects with one using as little as 5 while another used as many as 600 in a national survey (e.g., D'Andrade, 1976; Romney, et al., 1972). Stefflre (1972:214) stated: "This kind of data stabilizes with fairly small samples of respondents (N=30-60)." These techniques are not as reliant upon random selection or sample size for gaining statistical significance as would be found among other statistical procedures. Rather, it is more important in these procedures to sample subjects who have a shared understanding of the domain under study.

Like most anthropologists, we assume that members of human societies share beliefs and ways of behaving. These shared understandings and actions are what constitute "culture." In every human society, culturally coherent pools

[1]White, D. R., and H. G. McCann. 1981. Material and probablistic entailment analysis: Multivariate analysis of "If . . . then" statements in cultural systems. Manuscr. on file at School Soc. Sci., Univ. Calif., Irvine.

of information and knowledge are transmitted from individual to individual through processes of enculturation or socialization. In this research, our interests lie in describing the social behavior of recreational fishermen that may be directly attributable to the ways they categorize or rate fish.

All beliefs and perceptions will be affected by the degree to which subjects have been socialized into a particular system. In other words, an 11-year-old's understanding of their kinship system is less robust than, for example, his or her 30-year-old father's. We assume, of course, distinct parameters defining the nature and extent of knowledge about a particular domain. This knowledge is shared to varying extents among all members of the system—from a normative standpoint—and is passed on to new members through a socialization process. In this case, an individual who is new to recreational fishing will generally be socialized as a "recreational fisherman" through his or her experiences and subsequent discussions with more integrated members of the recreational "subculture" (e.g., at parties, bars, at home, on boats, on piers, etc.)[2] These assumptions guided our sample selection, in that we were interested in locating relatively experienced fishermen.

For the most part, fishermen in this study belonged to non-species-specific fishing clubs. Four such clubs were identified for data collection. These were located in and drew their members from east Florida, west Florida, Texas, and North Carolina. About 30 fishermen from each area were interviewed. A fifth sample of nonfishing club members was taken from the piers and other fishing spots in east Florida for comparative purposes (N=10)[3]. Some selected characteristics of the fishing club members and their fishing and fish preparation behaviors are included in Table 1.

Results

Hierarchical Clustering Analysis (HCL)

Table 2, a summary of the results of the HCL for the four regions[4], shows that the same general categories, presented along the left-hand side of the chart, were found in all regions. These categories reflect the general ways that marine recreational fishermen in each of the areas group species of saltwater fish. The boxes with the names of the fish represent the clusters of species that fishermen put together most often in the sorting tasks. As Table 2 shows, the general criteria that fishermen used to categorize species were:

1) Sportfish, or species that are fun or exciting to catch. In east and west Florida, fishermen differentiated between good-eating and poor-eating sportfish, while neither Texas nor North Carolina fishermen made these finer distinctions.

2) Meatfish, or fish that are good to eat. In addition to the meatfish designation, fishermen in all four regions separated their meatfish in terms of the ranges or habitats of the species. In all regions, the groupers and snappers were placed together and often described as "good-eating reef fish," while trout, bluefish, red drum,. etc. were described as "fish you can eat that you catch in the surf or from a pier."

3) A third category of lower quality or less well-known fish, also divided on the basis of range, begins the categories that contain species many fishermen reject. Texas fishermen lumped these species in with their "trashfish," while some fishermen in the other three areas acknowledged the utility of some of these species as fish they would use for bait. Most of these species, however, were perceived to possess one or two negative qualities, as will be seen below in the item-by-use matrices. These qualities made them less desirable than the fish in the second category.

4) Trashfish. Fishermen saw these species as the sea's least desirable. They used derogatory terms, such as "odd-ball species," "dangerous fish," "pisswinks," and "garbage," to describe these species. None were targeted for food or sport. A few fishermen had eaten puffer, calling it "the chicken of the sea," and an occasional favorable statement was made about gafftopsail catfish, but generally these fish were considered low on the scale of marine fishes.

Fishermen rejected these species for various reasons. In a few cases, the ugliness of these fish were cited. Others offered explanations that were, at least superficially, more reasonable. Searobins and puffers were said to be "all head and no meat"; puffers, poisonous; sea catfish, poor-tasting scavengers and dangerous to handle because they could use their spines like spears. Fishermen told of bad experiences with catfish, ray stingers, and the spines of searobins.

Species in this last category offended the fisherman's sense of what a fish should be—a scaled, silver, or colorful fish shaped like a grouper or cobia. But fish in category 4 have bumps, wings, stingers, blotchy and smooth skins like salamanders, and spines and whiskers like porcupines. They act strange, puffing up, grunting, or flying when tossed in the air.

One of the primary reasons for rejecting these species, then, is that fishermen tend to associate appearances and odd behaviors with undesirable characteristics. These findings are reaffirmed below in

[2]This is not to say that the population of U.S. marine recreational fishermen is homogeneous, consisting of a single language or ethnic group whose attitudes toward fish are uniform. In fact, there are segments of the total recreational fishing population to which our findings may not apply. For example, it could be argued that because the fishermen in our sample are overwhelmingly white males, drawn from fishing clubs, our findings cannot be extended to black, Hispanic, Korean, Vietnamese or other minority recreational fishermen in the United States. The basis for this argument lies in the findings of linguists and other social scientists, who argue that distance differences in linguistic behavior, socialization, and ethnicity between whites and these other ethnic groups result in different meanings, perceptions, and beliefs about the things of this world. It is important to note, however, that is has been shown more recently by Romney, et al. (1979) that ethnic enclaves in the United States may show more in common cognitively with the mainstream of American culture than is evident from casual observation. This seems to point to the importance of length of exposure to American popular culture (e.g., television, radio, etc.) and interaction with other social groups in the United States.

[3]To address the question of how similar fishing club members are to nonclub members, we compared responses from club and non-club members in east Florida with Pearson (0.78) and Spearman (0.63) correlation coefficients. These were significantly similar at the 0.0001 level for both tests.

[4]Clusterings were produced using the SAS average linkage procedure.

Table 1.—Selected characteristics of fishing club members.

Club membership data	East Florida				West Florida				North Carolina				Texas			
	Mean	Median	Mode	%	Mean	Median	Mode	%	Mean	Median	Mode	%	Mean	Median	Mode	%
Length of membership (years)	6.87	7.5	10		5.13	4.12	3		2.3	2	1		3.7	3.3	3	
Age	49.6	44.4	44		48.7	52	52		42.3	39	28		41.2	40	36	
Education in years	15.6	15	16		14.3	14.2	16		17.3	16.4	16		17	16.2	16	
Percent without HS diploma				4.2				0				0				5
Percent with HS diploma (only)				20.8				26.1				6.9				0
Percent with <4 years of college				29.1				34.7				6.9				5
Percent with 4 years of college				25.0				30.4				37.9				55
Percent with advanced degrees				20.9				8.7				48.3				35
Percent who own their own boats				91.7				56.5				60				70
Percent who clean, scale, etc. their fish themselves				96.0				100				93.3				90
0-20% of time				4.0				0				0				0
21-50% of time				12.0				4.3				3.3				0
51-99% of time				8.0				0				0				10
100% of time				72.0				95.7				90.0				80
Percent who have someone else clean, scale, etc. their fish				28.0				4.3				6.6				20
0-20% of time				8.0				0				0				10
21-50% of time				16.0				0				3.3				0
51-99% of time				4.0				4.3				0				0
100% of time				0				0				3.3				10
Percent who cook their own fish				72.0				78.3				86.7				55
0-20% of time				8.0				17.3				9.9				5
21-50% of time				12.0				17.3				20.0				10
51-99% of time				16.0				12.9				19.8				5
100% of time				36.0				30.4				36.7				35
Percent who have another person cook their fish				60.0				73.9				63.3				65
0-20% of time				8.0				8.7				13.2				5
21-50% of time				8.0				26.1				26.6				10
51-99% of time				20.0				26.1				13.2				5
100% of time				24.0				13.0				10.0				45
Cooking styles—1% of population who:																
Broil				59.1				78.3				73.3				55
Deep fry				59.1				65.2				73.3				65
Pan fry				22.7				34.8				16.7				5
Bake				31.8				39.1				40.0				30
Barbeque/grill				22.7				30.4				36.7				15
Smoke				31.8				26.1				10.0				5
Other				4.5				4.3				3.3				5

the entailment analysis. The notable exception to this is flounder. With two eyes on one side, often blotchy skin, and a flat body like a skate or ray, the flounder qualifies as unusual-looking fish. In fact, one fisherman told of tossing a flounder back before he learned from another fisherman what it was. The nearly universal utilization of flounder among marine recreational fishermen suggests that a fish which is good tasting and easy to clean will be utilized even if it does not approach the fishermen's ideal.

5) Sharks and dogfish, for obvious reasons, were lumped together by nearly every fisherman in the sample. For many, they comprised yet another group of trashfish.

Figure 1 converts the information from Table 2 into a tree diagram demonstrating the hierarchical levels at which the species are more closely or distantly related in terms of perceived and objective criteria. While the tree diagram (Fig. 1) and Table 2 both show that there is a great deal of agreement between regions in terms of the criteria used to classify saltwater fish, they also show that there is a great deal of overlap between regions in terms of the actual individual species that meet these criteria of sportfish, meatfish, and so on.

We draw three basic points from this information. First, in some cases, fish that are rejected by most fishermen (underutilized species) fall into categories with fish that are preferred. For example, while the poor-eating sportfish category in east and west Florida contains mostly underutilized species like amberjack, crevalle jack, etc., it also contains the highly sought tarpon; in North Carolina we find the generally undesirable pinfish and pigfish in the same pile with desirable croaker and spot.

Second, some fish that fall into rejected categories in one area fall into preferred categories in others. Mullet in west Florida is perceived as a higher quality fish than it is in east Florida; in Texas, mullet is considered a trashfish. Smaller species such as croaker and spot, while highly desired in North Carolina, tend to be scorned in east Florida or used only for bait.

Finally, and related to the second point, we see that the sizes and compositions of the categories vary greatly between regions. Texas has the largest trashfish or undesirable category and

North Carolina the most meatfish, for example.

This information tells us that, most importantly, some species have been classified as preferred or undesirable on the basis of local information, rumor, and the general processes that accompany being socialized into recreational fishing, rather than on the basis of more objective criteria. We will see below, in the item-by-use matrices, that fishermen consistently said "most people don't eat" about fish that they had never tried eating. In many cases it's obvious that a fish is underutilized in one region primarily because there's no tradition of utilization. Fishermen need only be informed that these fish are perfectly edible, and even good, and they will probably begin utilizing them.

One final point to be made here is that the availability of species tends to be a big factor in whether a fish is targeted or rejected. For instance, smaller species get worse ratings in east Florida than in North Carolina because bigger fish are perceived to be more plentiful and easier to catch in east Florida.

Multidimensional Scaling

Figures 2-5 present the MDS configurations for each of the regions[5]. The findings from the clustering analysis are complemented by the MDS analysis. Whereas in the clustering analysis we found that the two common categories of meatfish and sportfish came up in every region, in the MDS we found that the most common dimensions in all regions were:

1) Edibility (from good-eating fish to bad-eating or inedible fish) and

2) Sportfish (from large, strong fighting fish like wahoo and tarpon to the smaller, panfish types such as spadefish, searobins, and so on).

While these two dimensions appeared in all regions, they were clearest in east and west Florida and least clear in North Carolina. In North Carolina, there were a number of other criteria that muddled the dimensions of edibility and sport, such as the size, shape, and habitats of the fish.

Examining the MDS figure for east Florida (Fig. 2). for example, we can see that the flounders, snappers, and groupers fall to one side of the axis at the

Table 2.—Species clusters by major categories for the four regions: East Florida, West Florida, North Carolina, and Texas.

Major category	East Florida	West Florida	North Carolina	Texas
I. Sportfish	Amberjack	Amberjack	Amberjack	Amberjack
a. "Poor-eating."	Barracuda	Barracuda	Barracuda	Barracuda[2]
	Tarpon	Tarpon	Cobia	Pompano[2]
	Blue runner	Blue runner	Little tuna	Snook
	Crevalle jack	Crevalle jack	Dolphin	Tarpon
	Ladyfish	Ladyfish	Spanish mackerel	Cobia
	Rainbow runner		Wahoo	Spanish mackerel
			King mackerel	Wahoo
			Snook[2]	King mackerel
			Tarpon	
			Atlantic mackerel	
b. "Good-eating."	Cobia	Bluefish		
	Dolphin	Wahoo		
	Spanish mackerel	Cobia		
	King mackerel	Dolphin		
	Wahoo	Pompano		
		Snook[2]		
		King mackerel		
		Spanish mackerel		
II. Meatfish	Black sea bass	Black sea bass	Black sea bass	Jewfish
a. Offshore	Jewfish	Nasau grouper	Red snapper	Red snapper
	Gray snapper	Red snapper	Warsaw grouper	Black grouper
	Red snapper	Warsaw grouper	Nasau grouper	Schoolmaster
	Schoolmaster snapper	Scamp	Mutton snapper	Warsaw snapper
	Mutton snapper	Lane snapper	Red porgy	Nasau grouper
	Black grouper	Jewfish	Jewfish	Red grouper
	Nasau grouper	Red grouper	Gray snapper	Lane snapper
	Lane snapper	Black grouper	Lane snapper	Gray snapper
	Red grouper		Schoolmaster snapper	Mutton snapper
	Warsaw grouper		Black grouper	
b. Inshore	Bluefish	Summer flounder	Bluefish	Summer flounder
	Snook	Mullet	Mullet	Sand trout
	Southern kingfish	Sheepshead	Striped bass	Weakfish
	Northern kingfish	Weakfish	Weakfish	Red drum
	Summer flounder	Sand trout	Red drum	Southern flounder
	Sand trout	Beach whiting	Spotted trout	Spotted trout
	Pompano	Spotted trout	***	
	Striped bass	Red drum	Croaker	
	Red drum	Southern flounder	Summer flounder	
	Beach whiting		Pompano	
	Spotted trout		Spot	
	Southern flounder		Southern flounder	
	Weakfish		Pigfish	
			Sheepshead	
			White perch	
			Pinfish	
			Butterfish	
			Silver perch	
			Southern kingfish	
			Beach whiting	
III. Lower quality or less well-known meat fish[3]	Sheepshead	Queen triggerfish	Spadefish	No Texas clusters fit these designations.
a. Offshore	Tripletail	Schoolmaster snapper	Silver Jenny[2]	
	Scamp	Tripletail	Tautog/Blackfish	
	Gag	Gray triggerfish	Queen triggerfish	
	Queen triggerfish	Gag	Scamp[2]	
	Gray triggerfish	Mutton snapper	Gray triggerfish	
		Gray snapper	Tripletail	
			Gag	
b. Inshore[4] ("Baitfish")	Croaker	Croaker	Blue runner	
	White perch	Northern kingfish[2]	Northern kingfish	
	Flodia grunts	Silver perch	Crevalle jack	
	Pigfish	Southern puffer	Rainbow runner	
	Silver perch	Pigfish	Ladyfish	
	Spot	Spadefish		
	Spadefish	White perch		
	Mullet	Spot		
	Butterfish	Butterfish		
	Pinfish	Silver Jenny		
	Silver Jenny	Pinfish		
		Grunts		

(Continued on next page.)

[5]Stress figures for the scalings in three dimensions were: Texas, 0.171; east Florida, 0.170; west Florida, 0.157; and North Carolina, 0.145.

Table 2.—Continued.

Major category	East Florida	West Florida	North Carolina	Texas
IV. Trashfish[5]	Sea catfish Southern puffer Bighead sea robin Smooth puffer Northern sea robin Atlantic stingray Gafftopsail catfish	Sea catfish Northern sea robin Gafftopsail Catfish Smooth puffer Bighead sea robin Atlantic stingray	Sea catfish Smooth puffer Northern sea robin Gafftopsail catfiish Bighead sea robin Atlantic needlefish Red hake Southern puffer Atlantic stingray	Black sea bass Queen triggerfish Grunts Silver perch Spot Silver Jenny Smooth puffer Gag Northern sea robin Scamp Pinfish Bighead sea robin Southern puffer Blue runner Spadefish Ladyfish Pigfish Northern kingfish Rainbow runner Gray triggerfish *** Bluefish Sea catfish Crevalle jack Southern kingfish Mullet Gafftopsail catfish Croaker Sheepshead Beach whiting Striped bass Tripletail Stringray
V. Sharks/dogfish[6]	Blacktip shark (Spinner) Dusky shark Bull shark Sandbar shark Smooth dogfish	Mako shark Lemon shark Great white shark Sixgill shark Spiny dogfish		

[1]Neither Texas nor North Carolina differentiated between "good-eating" and "poor-eating" gamefish.
[2]Not well known in this area.
[3]These tend to be smaller, if known, and among the inshore species are those which are usually classified as baitfish. Also, because these fish are considered lower quality as food fish, the finer distinctions based on range and sporting qualities are not so strong in differentiating species from one another in these clusters. Fishermen's lack of experience with some of these species could cause the lack of finer distinctions as well.
[4]Species in this category were generally not well known in North Carolina. The "inshore" meatfish designation probably does not apply here.
[5]Texas "trashfish" species include species which were generally not well known to Texas fishermen; perhaps a better description of these clusters would be to say that they include those species Texas fishermen do not care very much about, nor know much about, nor care to catch.
[6]With the exception of West Florida, which differentiated the dogfish from the sharks, all the MCA results contained a cluster including all the sharks and dogfish.
***Break within a cluster.
****Break between clusters.

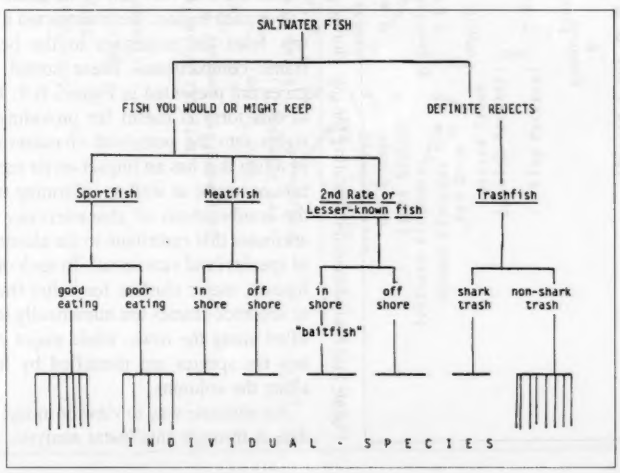

Figure 1.—HCL major clusters in tree diagram form.

"good-eating" extreme. As we cross the configuration, we encounter progressively less desirable species from an edibility standpoint. Thus, at the far end of the "poor-eating" fish we find such species as sharks, searobins, ladyfish, or tarpon.

The sportfish dimension can be seen from the top to the bottom of the Figure 2. The species get progressively more desirable as game fish or fish that are exciting to catch as you move from the spadefish (top) to tarpon (bottom).

The relative placement of underutilized species (dots) in relation to the utilized or preferred species (circles) was very helpful in developing the educational materials: We can visualize the similarities between species—as perceived by recreational fishermen—and then reinforce these similarities between underutilized and preferred species in the brochures, posters, and other educational materials.

The two dimensions of edibility and sport were found in all regions, but again, the precise locations of fish in relation to one another change from region to region, just as the species that fell into the clustering analysis categories varied between regions. Comparing east and west Florida, for example, we can see that the species at the extremes are almost identical: Tarpon is considered the most exciting sportfish and spadefish/pinfish the least, and the grouper/snapper species (those with white, delicate meat) are viewed in both regions as the highest qualify foodfish, and the sharks/catfish/searobins the lowest quality foodfish. Between these extremes, however, there are a few differences: Sharks are closer to tarpon in west Florida (indicating that it is considered a higher quality sportfish), and mullet and amberjack are a little closer to the "good-eating" end of the extreme in west Florida.

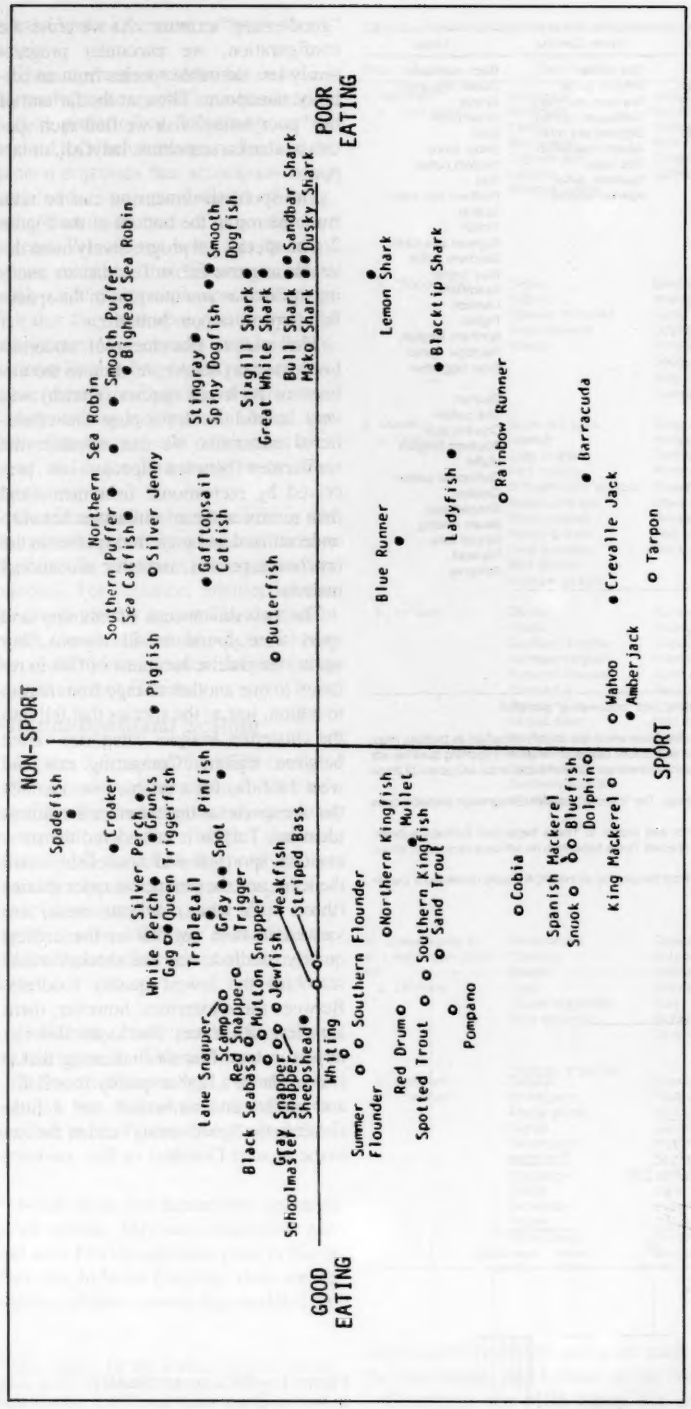

Figure 2.—Multidimensional scaling for east Florida: Dimension 1 vs. Dimension 2. Dots indicate underutilized species and circles represent utilized or preferred species.

North Carolina, on the other hand, is not nearly so well defined as east and west Florida in terms of the edibility and sport dimensions. This is because North Carolina fishermen seemed to group species on the basis of a variety of criteria, including size and shape, as well as the fight of the fish or its value as a food. In any case, it is still obvious that the hard-fighting fish cluster together at one end, the smaller species at the other, and that the groupers and snappers still fall into the same general region, opposite the trashfish.

Somewhat different than the other regions, Texans primarily distinguished between preferred and nonpreferred species. The three Texas favorites—spotted trout, reddrum, and flounder—all appeared together at the preferred end of the figure, and the nonpreferred species consist of both the good-fighting fish and the good-eating fish.

These differences reflect local preferences and further support our earlier contentions that the general criteria for targeting and rejecting fish remain more or less constant from region to region, while the specific stimuli that meet those criteria may vary.

Item-By-Use and Entailment

The results of the analysis of the item-by-use matrices are similar to what we found in the HCL and the MDS analyses. These matrices also have the added advantage of pointing out similarities and differences between the beliefs about fish (or similarities between belief-frames).

For each region, we constructed a matrix from the responses to the belief-frame comparisons. These sorted matrices are presented in Figures 6-9. Data in this form is useful for providing insights into the perceived characteristics of a fish that has an impact on its reputation or image as well as informing us of the combinations of characteristics and attributes that contribute to the clustering of species (and vice versa). In each of the figures, major clusters for belief-frames or sentence-frames are numerically identified along the rows, while major clusters for species are identified by letter along the columns.

An alternate way to view or model this data is through entailment analysis. Fig.

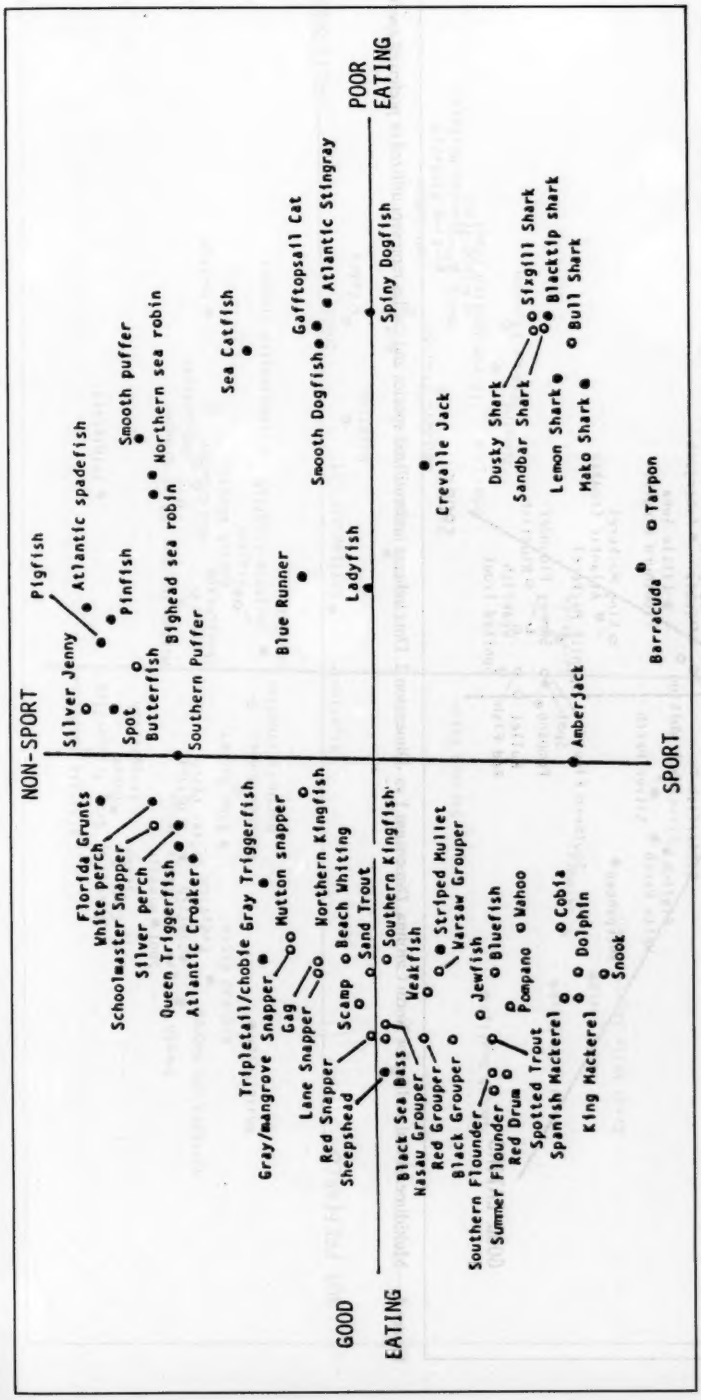

Figure 3.—Multidimensional scaling for west Florida: Dimension 1 vs. Dimension 2. Dots indicate underutilized species and circles represent utilized or preferred species.

ures 10 through 13 are entailograms showing both the implicational and contrast relationships among the belief-frames from the east Florida sample[6]. Cluster 1 (Fig. 10) contains belief-frames that are mostly negative in character. The following are two examples of how to interpret the diagram. The ordered relationship "only eaten by certain classes of people" entails that the fish is a "scavenger," which in turn entails that it "must be skinned." Many informants disparagingly described certain scavenger fish as being only eaten by certain classes of people. In addition, many of the scavengers were seen as requiring skinning (e.g., sea catfish).

A second example is the string "can only be cooked one or two ways" which entails that they "do not freeze well" (don't keep well in the freezer), which in turn entails that the "meat is oily-tasting." In contrast, for example, cluster II (Fig. 11) shows the relationship among positive characteristics with respect to freezing. Here the string "meat white when cooked" entails that the meat is "white when raw" which in turn entails that it will "freeze well."

Figure 13 shows examples of contrast relationships. Lines with cross-hatching denote these relationships. Contrast relationships are shown outside the clusters discussed above for the sake of simplicity and readability, but they could have just as well been included. An interesting example of such a relationship centers around the attribute "easy to clean." If a fish is perceived as "easy to clean," it will not be "poisonous," "ugly," or "slimy."

The importance of both the item-by-use and entailment analyses lies in their ability to inform and guide us in our attempts to change angler attitudes towards the less traditional sport fishes. These analyses, for example, tell us that fishermen routinely attribute negative culinary characteristics to fish they have never tried. It is much easier to change attitudes in situations where there is some degree

[6]Data from the east Florida item-by-use was dichotimized using the following break point: Alpha > 3. The entailogram was produced with the aid of a multidimensional Guttman scaling program written by Doug White at the University of California, Irvine. Relationships shown are with no exceptions.

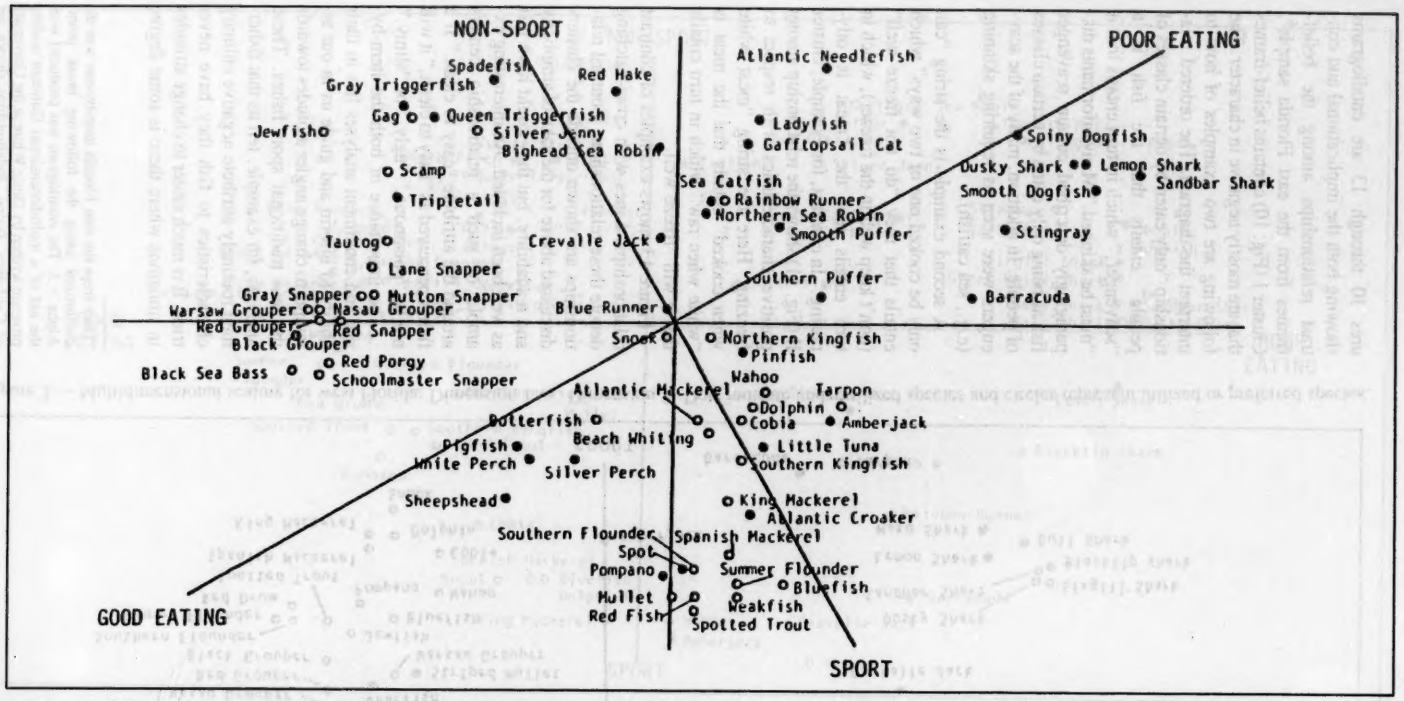

Figure 4.—Multidimensional scaling for North Carolina: Dimension 1 vs. Dimension 2. Dots indicate underutilized species and circles represent utilized or preferred species.

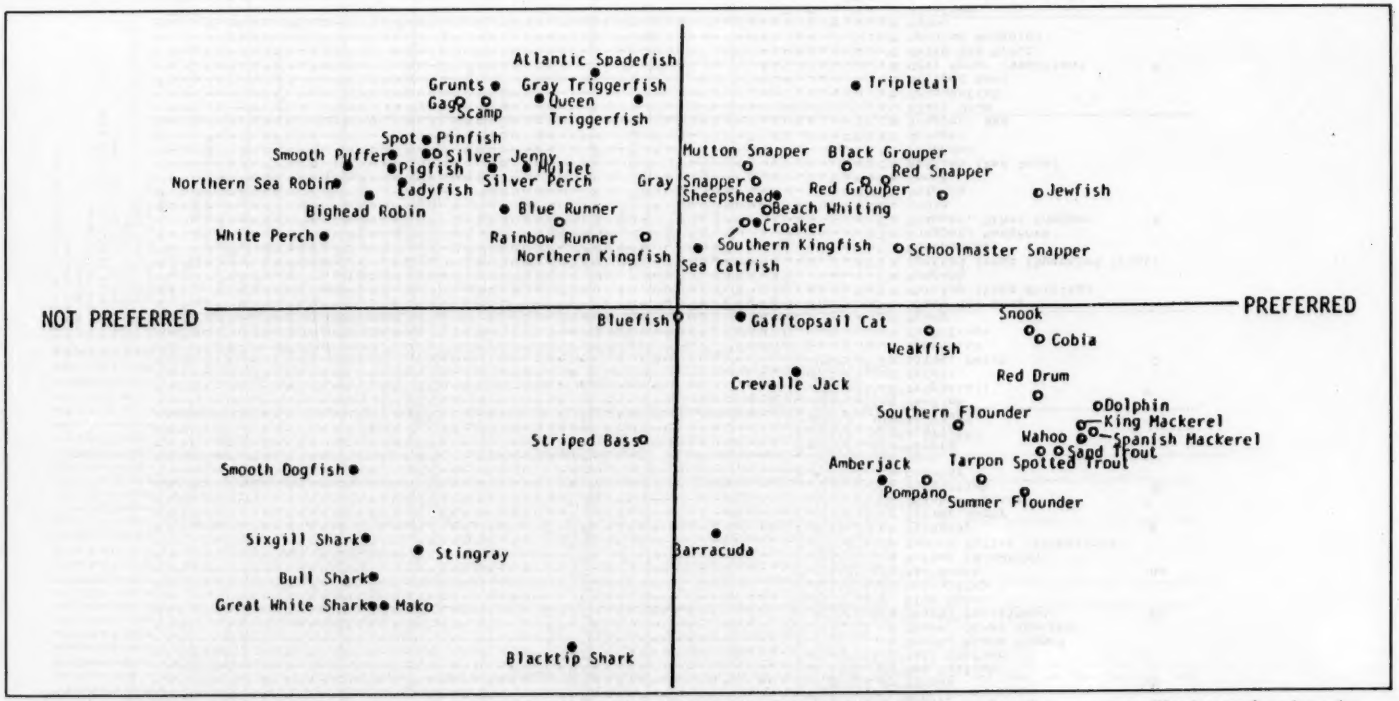

Figure 5.—Multidimensional scaling for Texas: Dimension 1 vs. Dimension 2. Dots indicate underutilized species and circles represent utilized or preferred species.

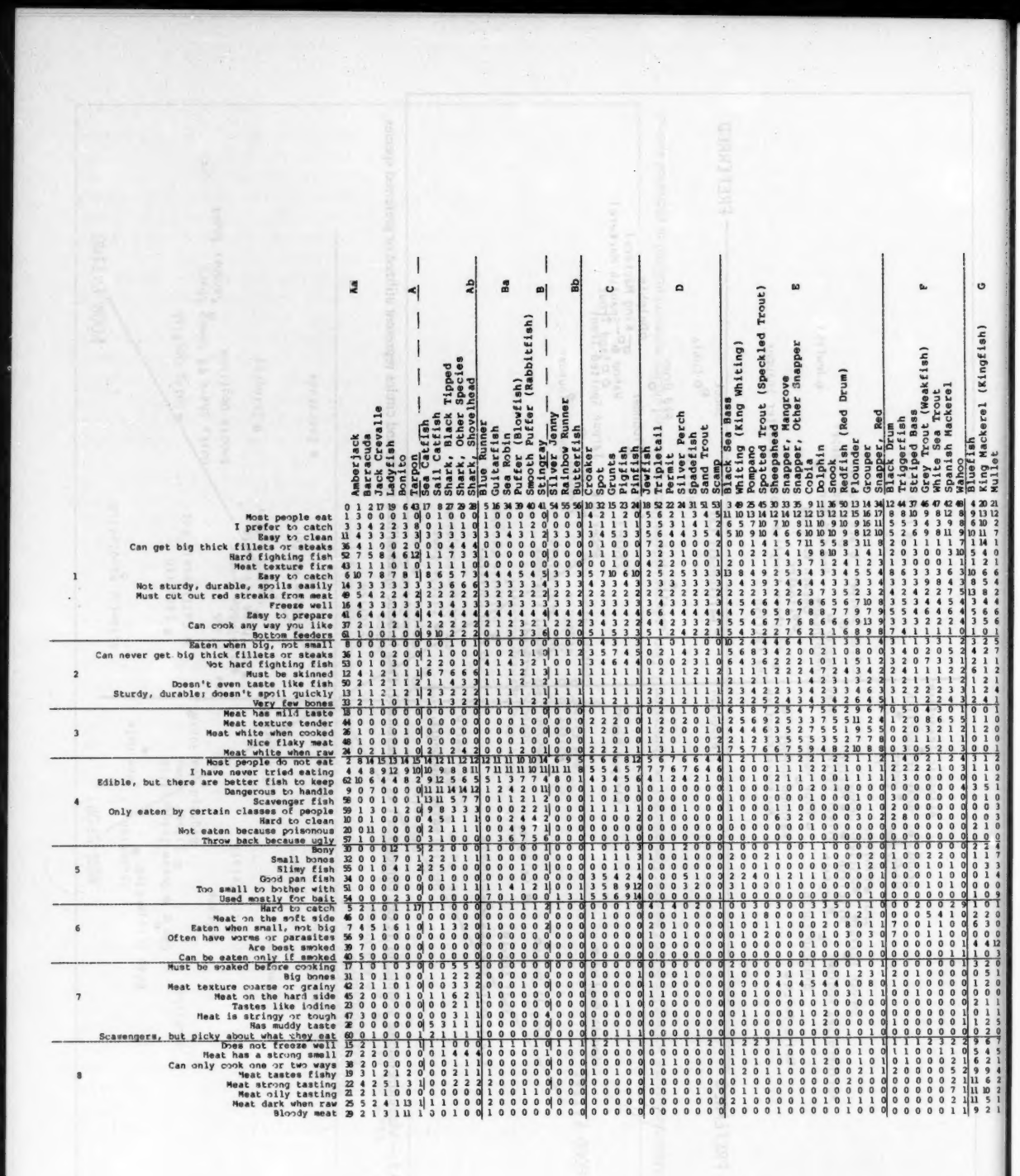

Figure 6.—East Florida sorted item-by-use matrix based on row-row and column-column similarities.

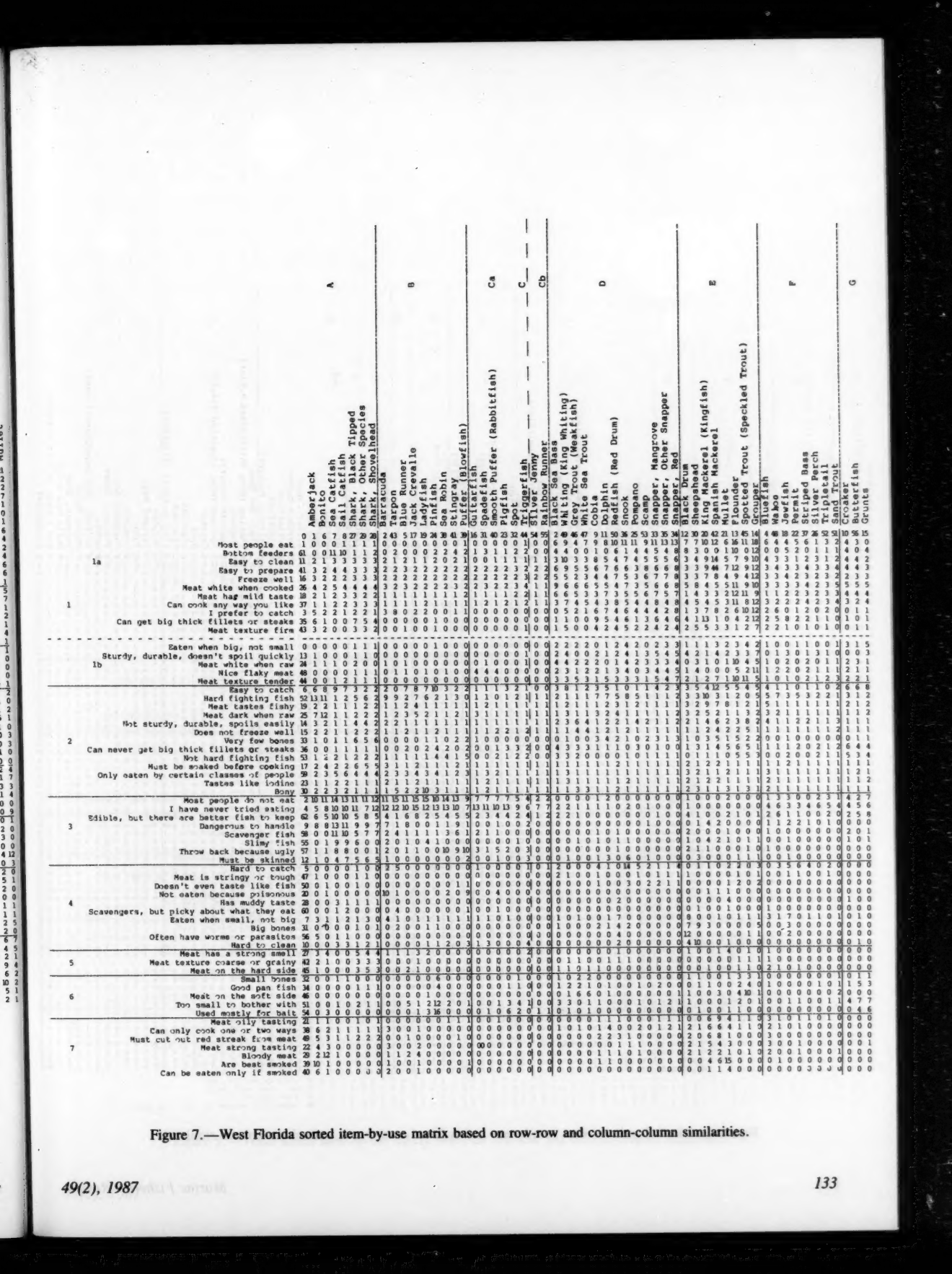

Figure 7.—West Florida sorted item-by-use matrix based on row-row and column-column similarities.

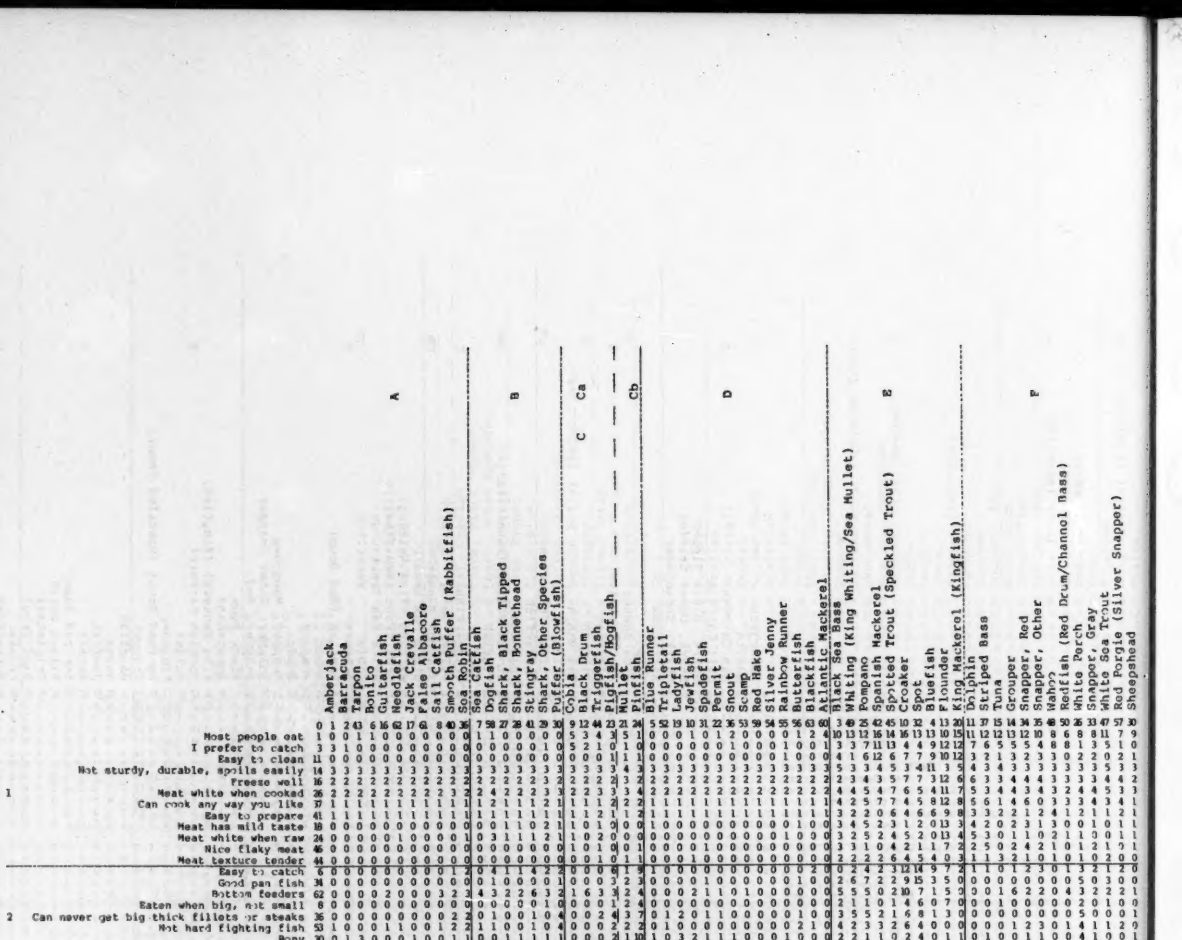

Figure 8.—North Carolina sorted item-by-use matrix based on row-row and column-column similarities.

Figure 9.—Texas sorted item-by-use matrix based on row-row and column-column similarities.

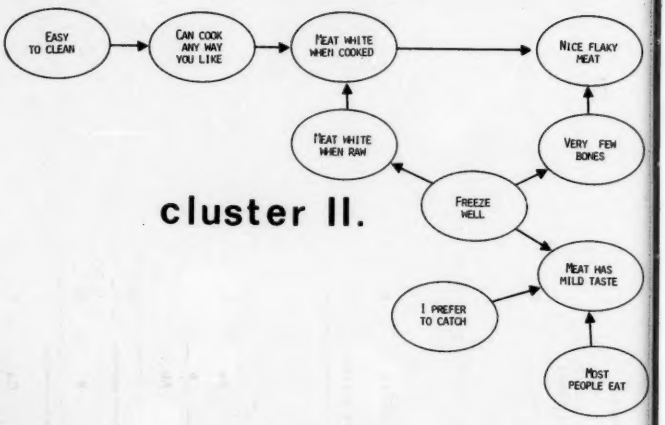

Figure 11.—Implicational relationships among positive belief-frames.

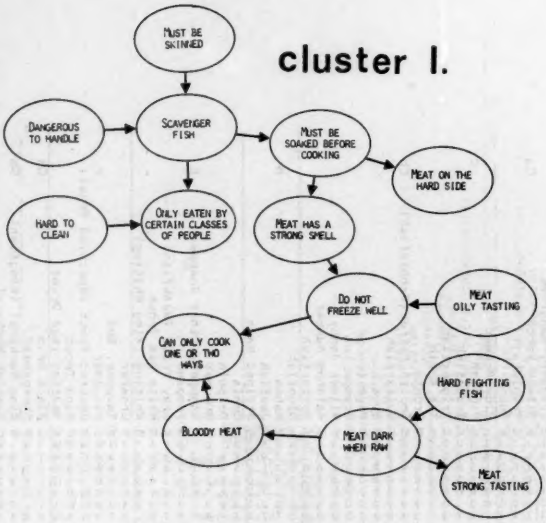

Figure 10.—Implicational relationships among negative belief-frames.

cluster III.

Figure 12.—Implicational relationships among a separate set of more negative belief-frames.

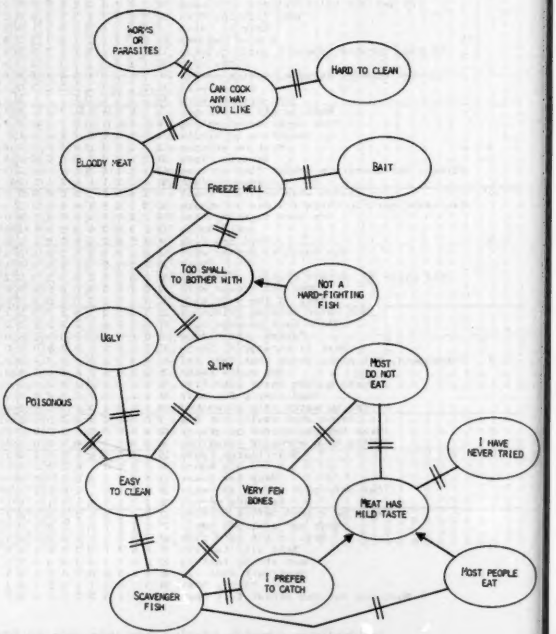

Figure 13.—Contrast relationships among belief-frames. Lines with cross-hatching indicate the contrast relationships.

of uncertainty; had fishermen actually eaten and rejected these fish, our task would have been much more difficult. In addition, this information helps establish parameters for determining an approach for enhancing the image of a particular underutilized species. Knowing what positive attributes to stress, and in what combinations (e.g., knowing the importance of the implicational relationships between "nice flaky meat," "meat white when cooked," cook any way you like," and " easy to clean"), can make a considerable difference in promoting fish. Similarly, and equally important, knowledge about negative attributes and their perceived relationships can help in determining appropriate ways to deal with the negative attributes of a particular species.

Discussion and Conclusions

These findings suggest that most perceptions concerning underutilized species are developed outside actual experiences. Beliefs relevant to these species are generally the result of hearsay and rumor perpetuated during a fisherman's socialization into recreational fishing. Ambiguities about the perceptions of underutilized species and lack of experience with such species are cognitively dealt with in terms of the general ways that recreational fishermen rank and classify fish.

Many of the findings of this study came as no surprise. That recreational fishermen target fish they perceive to be fun to catch, good to eat, easy to cook and clean, etc., are not earth-shattering revelations. Yet we would have suspected our techniques and interpretations had we not confirmed such banal knowledge. In many ways, this confirmation lends confidence to our findings.

This analysis has placed species of saltwater fish in relation to one another in terms of their similarities and differences as perceived by recreational fishermen. This information has served as the foundation for the development of educational/advertising materials designed to improve the reputations of underutilized species, thereby promoting their use. The methods used in the study complement one another in this regard. While the HCL yielded an understanding of the general perceived similarities and differences among species, the MDS further defined relationships between the species in terms of the specific dimensions of sportfish and meatfish. These relationships suggest possible ways that underutilized species' images may be improved via favorable comparisons with preferred species that, in the minds of fishermen, they already resemble. These relationships between species also suggest which underutilized species are the most and least likely to improve with an educational program. The item-by-use matrices and entailment analyses further defined relationships between the species in terms of attributes suggested by fishermen. An understanding of the relationships between attributes (belief-frames) suggests the proper and most appropriate ways to present a case for the increased utilization of underutilized species within an educational context. Together, the three types of information provide a clear and workable picture of the domain of saltwater species as perceived by people who regularly and actively deal with them.

Knowing what fishermen like or do not like and understanding the manner in which they express their beliefs concerning fish is critical for producing appropriate and effective educational materials. In Part II, (Murray et al., 1987) we look at the application of this information to the development of educational materials directed at encouraging marine anglers to better utilize nontraditional fish in the southeastern United States.

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Encouraging the Use of Underutilized Marine Fishes by Southeastern U.S. Anglers, Part II: Educational Objectives and Strategy

JAMES D. MURRAY, JEFFREY C. JOHNSON, and DAVID C. GRIFFITH

ABSTRACT—This paper, the second of a two-part series, focuses on the educational program and the process of increasing demand for underutilized marine fishes by recreational fishermen in the southeastern United States. Short- and long-term objectives, strategy, development of educational materials, and results are discussed. We point out how the species were selected for development and how the research findings influenced the information presented in the materials. The advantages of initiating projects that contain both research and extension components are pointed out. We show how marketing and consumer behavior research techniques can be used to shape an educational program. Also discussed is the importance of producing multifaceted educational materials and training a network of educators to conduct educational programs to achieve widespread distribution and adoption of information.

Introduction

In Part I of this study, Johnson et al. (1987) gathered information about southeastern U.S. marine recreational fishermen's perceptions of and preferences for marine fishes. In Part II we initiated an educational program to change the sport fisherman's beliefs about selected underutilized marine fishes.

Given the potential benefits of increased utilization, the question becomes: How do you change the sport fisherman's attitudes and behavior toward nontraditional species? There are, of course, many steps involved in this process. They include basic research, development of consumer education materials, and distribution of these materials. Although all these steps are important in effecting change, we concentrate on the educational component in this paper, Part II.

The long-range goals of the overall project were to: 1) Reduce conflicts between sport and commercial fishermen, 2) enhance tourism at the local level by increasing the demand for sport-caught underutilized species, 3) increase the consumption and reduce the waste of recreationally caught underutilized species, and 4) enhance the recreational fishing experience by emphasizing positive attributes of various underutilized species.

These goals fit within the mission of the National Sea Grant Program, which has a basic goal "to promote the wise use and conservation of our nation's marine resources." And, the goals were consistent with the Program Development Plan of the Southeast Region, National Marine Fisheries Service, for marine recreational fisheries. The plan had proposed activities to distribute information on opportunities for increasing use of sport-caught species (NMFS, 1983).

Educational Program and Objectives

We developed educational objectives with a general goal of having 50 percent of the estimated 9 million marine anglers in the southeastern United States better understand recreational fishing opportunities for selected underutilized species over a 10-year period. Achieving such a goal will not be easy or immediate. An orderly, long-range informational program should be multifaceted and should include different strategies for different species and angler audiences.

In this case, the informational tools were diverse. We used a mix of radio, television, publications, news articles, video productions, and special events to reach the recreational fishing public. Even though the project will end, the program developed will not. The project goal was to develop lasting materials that will be easy to use by a variety of marine educators and sportfishing opinion leaders.

Specific objectives of the educational program were to: 1) Develop a variety of educational materials, based on the research discussed by Johnson et al. (1987) in Part I, for distribution throughout the southeastern United States, and 2) develop a network of sportfishing opinion leaders and educators and inform them on the use of these products to achieve a "snowballing" effect.

Procedure

The first step in developing the educational program was to analyze the data from Johnson et al. (1987) and determine general perception patterns regarding fish. Popular or target fishes usually ranked high on four characteristics: Availability, reputation, edibility, and fighting style. Even though most target species ranked high on these four characteristics, it was not mandatory for target species to be graded high on all four. For example, the tarpon, *Megalops atlanticus*, is a target species, but it ranks low in

James D. Murray is Director, Marine Advisory Service, UNC Sea Grant College Program, North Carolina State University, Raleigh, NC 27695. Jeffrey C. Johnson is Associate Scientist and David C. Griffith is Assistant Scientist, Institute for Coastal and Marine Resources, East Carolina University, Greenville, NC 27858-4353.

edibility and availability. However, it ranks high enough in reputation and fighting style to outweigh the negative characteristics. Ultimately, 16 marine fishes (Table 1) were chosen for increased utilization by sport fishermen. All ranked high on at least one of the four characteristics, allowing us at least one positive trait or characteristic upon which to build an educational program.

Aside from the four general characteristics mentioned above, we discovered several other factors which were important in understanding perceptions and thus building an educational program. For several species of fish, regional variations in perception were found. For example, greater amberjack is more likely to be targeted in the Gulf than in North Carolina, while mullet is more likely to be sought in Florida than in Texas. Atlantic croaker is a popular sport fish in North Carolina, but is likely to be ignored in Florida. Because of such variations, we decided to use the positive impressions of a fish in one region to help overcome negative attributes the fish had in another region.

We also found that sport fishermen often obtain information from other anglers without learning it firsthand (Johnson et al., 1987). The fishing "grapevine" works, and many fishermen will go to great lengths to relate that a particular fish is "hard to clean" or "tastes sour." But, when asked if they have tried the fish, the answer is quite often "no."

The following hypothetical example shows how some misinformation can start. When a fisherman catches a shark, he may throw it on the deck so pictures can be taken when he reaches the dock. Later he takes it home in the evening and cleans it. And then, when he cooks it a day or two later, it does taste "sour." He then may tell his fishing friends that he's tried shark and "even his cat wouldn't eat it." In this case the angler's first mistake was in treating the shark as he would any other fish. He did not realize shark should be bled, gutted, and iced within 20 minutes.

Our strategy was to turn this information "grapevine" to our advantage. We targeted the sportfishing opinion leaders to whom the average fisherman is most likely to look to for information. And we tried to change their attitudes about the selected underutilized species.

Table 1.—Species or species groups of marine fishes selected for improved utilization by sport fishermen in southeastern United States waters

Greater amberjack, *Seriola dumerili*[1]
Northern searobin, *Prionotus carolinus*[2]
Skates and rays[2]
Rajiformes (various species)
Gray triggerfish, *Balistes capriscus*[1]
Panfishes[2]
White grunt, *Haemulon plumieri*
Silver perch, *Bairdiella chrysoura*
Pinfish, *Lagodon rhomboides*
Crevalle jack, *Caranx hippos*[1]
Sharks[1]
Shortfin mako, *Isurus oxyrinchus*
Blacktip shark, *Carcharhinus limbatus*
Lemon shark, *Negaprion brevirostris*
Sheepshead, *Archosargus probatocephalus*[1]
Atlantic bonito, *Sarda sarda*[1]
Atlantic croaker, *Micropogonias undulatus*[2]
Black drum, *Pogonias cromis*[1]
Bluefish, *Pomatomus saltatrix*[1]
Ladyfish, *Elops saurus*[1]
Striped mullet, *Mugil cephalus*[1]
Pigfish, *Orthopristis chrysoptera*[2]
Ocean catfishes[2]
Gafftopsail catfish, *Bagre marinus*
Hardhead catfish, *Arius felis*

[1]Potential target species.
[2]Incidentally caught species in need of greater utilization.

For example, if an unfamiliar fish looks "different," it is not perceived to be good. Examples include skates and rays, searobin, triggerfish, and Atlantic spadefish, *Chaetodipterus faber*. But we were able to draw upon exceptions to this rule to help overcome some misconceptions. For example, the odd appearing flounder is highly sought by some anglers but not others. To help fishermen overcome the hesitation of trying something new or different, we selected and used relevant anecdotes. For example, one fisherman told us that when he first moved to Florida from a northern state, he threw back all the flounder he caught until he discovered what they were. He didn't think anything so "ugly" could be a flounder. We used such stories to convince fishermen to try such species such as searobin.

We also found that if a species requires special handling, it is not as likely to be utilized (Johnson et al., 1987). Sharks, skates, and rays need to bled and iced within 20 minutes or off-flavors will develop. Most fishermen don't know this and, when they treat these fishes like other (nonshark) species they have poor results. Triggerfish require different cuts than a typical trout-type fillet. Sea catfish need to be skinned, and other fish such as Atlantic bonito, need to be bled and iced rapidly upon landing. When fishermen lack this information they often have bad experiences with the fish.

As discussed in Part I, dark-meated fishes (i.e., crevalle jack, Atlantic bonito, and bluefish) were not viewed as well as species with lighter flesh, although there are some exceptions. King mackerel is generally considered to have darker flesh, but it is extremely popular. Similarities with king mackerel were highlighted in information regarding bluefish.

The need to use different fishing methods is sometimes an obstacle to utilization. Atlantic spadefish, for example, will not strike an artificial lure or typical cut bait. Their diet consists of sponges, tunicates, and sea anemones, and they can be caught by fishing with jellyfish. Information on this technique, developed by the South Carolina Division of Wildlife and Marine Resources, was distributed widely with apparent success.

Selecting Species

To determine the species to target for an informational program, we reviewed the data in Part I (Johnson et al., 1987). Multi-dimensional scaling and hierarchical clustering techniques were used to determine the judged similarities and differences between the different species. This facilitated an understanding of relationships between the species and helped to identify both their positive and negative attributes. The item-by-use procedure and entailment analysis helped determine the relationships between the attributes.

Finally, 16 species or species groups, were selected (Table 1). Those chosen either had attributes which were similar to popular species, or information about their positive characteristics was lacking. The list was approved by the Southeast Regional Office of the National Marine Fisheries Service prior to developing the educational program. This step was necessary to make certain NMFS biologists did not see immediate future stock concerns with the resource. Puffers, *Sphoeroides* spp., and great barracuda *Sphyraena barracuda*, were not approved by NMFS because of potential health problems associated with toxins.

Information is needed for these species, but it was determined that misinterpretation or improper application of it could lead to serious health risks, and they were therefore left out.

In general, the 16 species fell into two broad categories: 1) Fish which could become potential target species and 2) incidentally caught fish which could be utilized to a greater extent. Potential target species included amberjack, triggerfish, ladyfish, and crevalle jack. Species caught incidentally which could be more fully utilized included searobin, skates and rays, and several of the "panfishes".

Crevalle jack and ladyfish, which are plentiful, easy to catch, and good fighters, are not targeted owing to their edibility characteristics. For those species we suggested alternative uses such as inshore tournaments for newcomers to marine fishing. We also discussed preparation methods which overcome their shortcomings as food fishes. On the other hand, we assumed that fishermen probably were not going to target dogfish sharks (Squalidae) or searobin. Both species, often caught while fishing for other more popular fishes, are usually discarded. The dogfish and searobin information centered on preparation methods so more would be used and fewer discarded.

Materials

We produced a variety of materials to get our messages across. Our basic approach was to confront the species' negative images and to emphasize their positive characteristics. By confronting the negative perceptions, we felt the information would be more believable to fishermen. For example, we admitted that amberjack have worms, but pointed out that other popular species, such as groupers, do too. We also noted that any area that obviously contains the worms (usually the meat near the tail) can be removed. The remaining amberjack meat is white when cooked and compares in quality and texture with other highly desirable species.

Where possible, we provided examples of the use of the underutilized species from other regions, countries, or from the commercial fishing sector. Examples here include mullet (highly utilized in Florida but not in Texas) and searobin (used extensively in Europe and one of the ingredients in classic French bouillabaisse). Also, a commercial fishery exists for crevalle jack in Florida, and the meat is frequently sold in Central and South American markets.

Additionally, our research in Part I provided clues as to how experienced fishermen used some of the species. For example, we found that ladyfish were targeted in a "powderpuff tournament" in Florida. Therefore, materials discussed the ladyfish as a candidate for "powderpuff," children's, and senior citizen's fishing tournaments in the Florida area.

Another strategy was to develop a combination of short idea-generating materials and more in-depth information for fishermen who take a more serious interest in a species. News releases, posters, and radio and television spots accomplished the former, while the brochures, recipe book, and tournament publication accomplished the latter.

A 21-minute slide-tape program with 133 slides was developed primarily for sportfishing club meetings. The professionally narrated program visually introduced the project and directed fishermen how to obtain the other materials. The program was also produced on videotape. Free copies were distributed to each Sea Grant program and state fisheries agency in the southeast region, as well as to the National Marine Fisheries Service and Sport Fishing Institute. Copies are available through the UNC Sea Grant Program for a 2-week loan or for sale (slide-tape, $65; video, $15). Accompanying the program is a teacher's manual, which describes the project and gives a third party (i.e., a sportfishing club program chairman) enough information to be able to introduce the program. The slide-tape has also been used by other groups (i.e., civic clubs, Boys Scouts, 4-H, power squadrons, and school groups).

A set of 12 posters, each highlighting major points about a different species, was developed for public places where fishermen were likely to gather. For example, the poster on skates and rays compared their flavor and texture with the highly prized scallop. It also provided in-

high speed cruisers looking for a fight
amberjack
■ Pound for pound amberjack is one of the best fighting fish.
■ A few simple steps yield large quantities of high quality meat.
■ Amberjack's firm, light meat is excellent baked, charcoaled, broiled or smoked.

Amberjack poster.

structions on bleeding and icing skates and rays, tips on avoiding the barbs, and drawings showing a five-step method of dressing a skate. All posters directed readers to the UNC Sea Grant College Program for more information. To encourage retail stores to display the posters, they were professionally and attractively designed and brightly colored. Free posters were sent to bait and tackle shops, fishing piers, marinas, and charter and head-boat captains throughout the region.

Brochures were produced (12,000 each) for all 16 species, and they were the backbone of the educational materials. Each began by highlighting the major

messages about the species. Additional information was provided on each species' life history, tips on how and where to catch them, and data on preserving, dressing, and preparing them, including some recipes.

Because tournament fishermen were considered to be opinion leaders, we attempted to introduce underutilized species at traditional saltwater fishing tournaments. For example, we helped a traditional king mackerel tournament add a prize category for greater amberjack, and we developed an inshore tournament for crevalle jack, Atlantic spadefish, and skates and rays. Here, our aim was to determine if this appraoch had merit and, if so, to gain first-hand experience with it. A booklet titled "Using Nontraditional Fish in Saltwater Sportfishing Tournaments" by Murray et al. (1986) was published, and our results were discussed at the National Sportfish Tournament Directors Conference in Miami, Fla., in 1986.

Many of the problems associated with underutilization of marine fish by anglers center around a lack of information about a fish's edibility characteristics. Each brochure contained two or three recipes for a given species. These and other recipes were compiled in a recipe book (Murray and Taylor, 1976) which contains more than 50 recipes as well as tips on bleeding, icing, and dressing many of the species.

These materials provided reinforcement for a variety of other educational activities. They were used as handouts when addressing sport fishing organizations. They accompanied news releases to the print media. And, they served as a backdrop for boat shows, sportfishing shows, and other exhibits attended by large numbers of recreational fishermen.

Mailing Lists

The investigators felt strongly that if the program were to work, it must be pro-active rather than reactive. Besides developing the written materials, we developed mailing lists of sportfishing opinion leaders in the southeast region. Opinion leaders were identified as fishing pier owners, bait and tackle shop owners, members of sportfishing clubs, outdoor writers, marina owners, charter boat captains, tournament directors, Sea Grant advisory agents, and state and Federal fisheries agency personnel.

Sources used to compile the mailing lists included directories from the state and Federal fisheries agencies and Sea Grant institutions, and in some cases, telephone directory yellow pages. Over 2,000 opinion leaders were placed on our mailing list, and they received the brochures and posters, as well as the news releases about the other products.

Developing a Network of Educators

Recognizing that the project was geographically large and should be of long duration, we decided to form a network of educators in the southeast region who could work locally and continuously with their constituencies. To actively encourage their participation, we asked the directors of the Sea Grant Marine Advisory Services and the state recreational fisheries programs to appoint one person to act as liaison with this project. This gave us one university and one state agency contact in all eight southeastern coastal states. Of the 16 possibilities, we had 15 participating.

Funds were provided to cover their travel to an indepth, 2-day training program covering the research, the materials, and the potential uses of them. A meeting was held in Charleston, S.C., in 1985 for representatives of the south Atlantic states and in 1986 in New Orleans, La., for the Gulf states. The meetings were open to other educators and interested parties (i.e., Gulf Coast Conservation Association). At the end of the meetings we distributed bulk quantities of the written materials, news releases about the program, and materials for participants to take to their home state. Since agents are better known locally by the press, news releases from them were more likely to be printed. It also reinforced the role of the local agent as the conduit for information.

Results

Part I (Johnson et al., 1987) provided useful information on marine angler's perceptions of target and nontarget fishes. The information formed a solid basis for designing an educational program to increase use of underutilized species. It showed us where there was potential for improvement of a species' "image" or how improving the image could be accomplished by pointing out its similarities with more desired species. The procedures show how understanding the relationships among attributes can provide guidance in producing culturally appropriate descriptions of nontraditional species. They can help in identifying speices with the most potential for increased utilization and can provide critical guidelines for the production of educational materials.

Once the perceptions that influenced behavior were understood, a more effective educational program could begin. The overall goal of extension education is to stimulate behavior change. In essence, an educational effort should stimulate someone to do something different as a result of the information provided.

In this program, our long-range goal was to have 50 percent of the fishermen in the southeast region utilize new species of underutilized fish. As mentioned, this is a 10-year goal that will be difficult to evaluate even after 10 years. We are presently conducting a survey of individuals who have requested our materials to determine whether or not they changed their fishing patterns or use of fish as a result of their exposure to our program and materials.

While a formal evaluation of behavioral change has been launched, other quantitative and anecdotal evidence indicates that the program and materials have been well received. The slide-tape program was shown at least 35 times during 1986. This does not include the presentations that have been given by state agencies or agents who have access to the slide-tape program in their own states. An evaluation of the slide-tape program was sent to all individuals who used it. Of the 20 respondents, all recommended the program for showing to other groups similar to theirs.

The first series of 10 brochures was printed in December 1985. By December 1986, about 8,000 of the 12,000 copies of each brochure were distributed for a total of 80,000 brochures distributed in the first year of the program. Although some of the distribution was in bulk form

to agents, the majority were distributed by individual requests. During the first 3 months of the program we received an average of 500 individual requests per brochure per month[1]. The brochures also stimulated many letters and phone calls from fishermen. The print and electronic media were sent the brochures which triggered radio shows and newspaper and magazine coverage. For example, a daily St. Petersburg, Fla., newspaper covered the project and finished with a recommendation to contact the NMFS Southeast Regional Office in St. Petersburg for copies of the brochures. This generated over 200 phone calls and about 40 visitors to the SERO the following day.

The Scotts Hill, N.C., King Mackerel Tournament, which added a greater amberjack category for its 1985 tournament, was satisfied with the results and doubled the prize money for the species in 1986. They again asked UNC Sea Grant for assistance with news releases, filleting and cooking demonstrations, and brochures for distribution at the tournament. In 1986 three major king mackerel tournaments in southeastern North Carolina added greater amberjack as a prize category and two of the tournaments recorded 8,000 and 6,000 pounds of greater amberjack landings. Several underutilized species tournaments have developed in the Gulf region, and a tournament scheduled in the Tampa, Fla., area for 1987 will concentrate on ten underutilized species.

The recipe book retailed at the UNC Sea Grant printing cost ($2 per copy), and the agency had 1,000 individual prepublication requests for it. It also stimulated many articles by food editors in southeastern newspapers. Our materials were displayed at the Lobo Sportfishing Show in New Orleans, La., and the Miami Boat Show. Although a fair amount of interest was generated at the shows, we felt they were not a cost-effective way to alert the public to the program. Future attempts will be made to distribute materials through other sportfishing organizations which have booth space at shows rather than doing it on our own.

[1]According to the communications staff of the UNC Sea Grant College Program (personnal commun.), the brochures were the most popular UNC Sea Grant publications in the past 6 years.

Conclusions

1) Marketing research techniques can be used to understand attitudes of marine recreational fishermen. Too often, educational and promotional materials are developed without a full understanding of what the perceptions are that we are trying to change. By understanding the perceived positive and negative attributes of the various species fishermen catch, we were better able to structure the educational products to overcome the negative perceptions or to enhance the positive ones.

2) Where appropriate, research and extension should be built into a project like this one from the beginning. The investigators on this project represented both the research and extension communities. The extension component was able to help structure the research, and the researchers were able to help the extension component implement the research findings. Often, research is done without a clear view of implementation of the findings. Similarly, extension is often done without a firm research base upon which to build the educational efforts. This project included the total package from the beginning, thus avoiding these potential problems.

3) Judged similarities of fish were obtained from recreational fishermen and their perceptions were used in the educational materials and program. This format added to the credibility of the materials.

4) A multifaceted educational program allows the educator to reach a greater audience. The materials targeted different sportfishing audiences. When trying to reach a large and diverse audience, it is beneficial to categorize the population and target different materials to these different segments. It is also important to develop a good mailing list. Rather than waiting for the clientele to contact us for information, the opinion leaders were identified and were sent the materials unsolicited.

5) Training others to become familiar with the entire program is an important step in getting others to use it. Most extension agents and educators are quite busy conducting their routine programs. A news release is not generally sufficient to interest someone to discontinue one program and begin another. Providing in-depth training sessions and paying travel expenses to attend will help make educators active participants in the program. This will generate enthusiasm, a better knowledge of the goals and objectives, and greater utilization and dissemination of the information.

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Using FAD's to Attract Fish at Coastal Fishing Piers

JAMES D. MURRAY, JEFFREY C. HOWE, DAVID G. LINDQUIST, and DAVID C. GRIFFITH

ABSTRACT—Eighteen midwater fish aggregating devices (FAD's) were deployed alternately off the ends of two piers (one acting as a control) in Wrightsville Beach, N.C., to evaluate their ability to attract coastal fishes. Creel censuses of pier fishermen and diver surveys of FAD's were conducted to determine: 1) The aggregation capabilities of FAD's, by number, size, and fish species; 2) the effect of FAD's on catch per unit of effort by species; and 3) the durability of the FAD's in this environment.

Results of the study were mixed. The FAD's proved to be successful in aggregating baitfish in the nearshore environment. An average of 3.67 ± 8.91 fish, representing 35 different species, appeared on each FAD. The control site had no fish. The FAD units were not successful in improving fishing success at the fishing piers most likely due to the distance of placement from the end of the pier (229 m). The FAD units were durable enough to hold up under normal conditions, but slightly more than half of the FADs were lost and most were damaged during a Category 2 hurricane.

Introduction

Several hundred fishing piers line the coast of the United States, providing hundreds of thousands of man days of recreational fishing. The North Carolina coast contains 34 fishing piers (Goldstein, 1978), each providing thousands of man days of recreational fishing per year. These piers contribute significantly to the local economies where they are located.

For many years pier owners have grappled with the idea of improving fishing by concentrating fish near the pier. Traditional artificial reef development has been impossible because: 1) It would place obstructions on the bottom where pier fishermen would lose their gear, 2) it is difficult to obtain permits to place hard rubble on the bottom in the surf zone because of the potential for erosion problems, and 3) the placement of a hard-rubble reef would be expensive.

Therefore, about the only method of fish enhancement attempted has been to chum off of piers. However, chum availability and its high costs have been a problem in recent years, and this practice is no longer used.

In recent years, in part because of rising energy costs, there has been increased effort toward the development of midwater fish aggregating devices (FAD's). The purpose has been to aggregate fish to reduce the search time for both commercial and recreational fishermen. Work by Shomura and Matsumoto (1982) demonstrated that such units will aggregate pelagic fish in offshore areas. In most cases, they indicated a doubling or tripling of fish catches. Wickham et al. (1973), Wickman and Russell (1974), and Hammond et al. (1977) showed that various kinds of midwater structures were attractive to coastal pelagic sportfishes off Panama City, Fla., and the central South Carolina coast. Again, these studies indicated a doubling in sportfish catches when compared with unenhanced control areas. A South Carolina study using midwater attractors as trolling alleys (Myatt, 1982) demonstrated an 80.3 percent increase in trolling strikes over the midwater attractors when compared with trolling over similar unimproved ocean areas. And, Workman et al. (1985) reported that deployment of an adequate number of strategically positioned FAD's should enhance the potential for aggregating harvestable concentrations of commercially and recreationally important fishes.

In the fall of 1983, a grant was obtained from the UNC Sea Grant College to investigate the potential of FAD's to aggregate fish in the nearshore ocean environment and to determine if they would improve the catch per unit of effort on nearby fishing piers. We hypothesized that the FAD units would remain intact in the nearshore environment and that pelagic sportfish would be attracted to the FAD units. We further hypothesized that these fish would move back and forth from the units to the pier and be available to anglers. Specifically, the objectives were to:

1) Determine the FAD aggregation capabilities by number, size, and fish species;

2) Determine the durability of the FAD's in this environment; and

3) Determine the effect of the FADs on catch per unit of effort by species on a North Carolina fishing pier using a control pier as a base.

Materials and Methods

Study Area Description

The primary factors associated with choosing a study site were the proxim-

James D. Murray is Director, Marine Advisory Services, UNC Sea Grant College Program, Box 8605, North Carolina State University, Raleigh, NC 27695-8605. Jeffrey C. Howe, formerly a graduate research assistant, Department of Biological Sciences, University of Wilmington, is presently at 1508 Kewalo Street #202A, Honolulu, HI 96822. David G. Lindquist is Professor, Department of Biological Sciences, University of North Carolina at Wilmington, 601 College Road, Wilmington, NC 28403. And David C. Griffith is Assistant Scientist, Institute for Coastal and Marine Resources, East Carolina University, Greenville, NC 27858-4353.

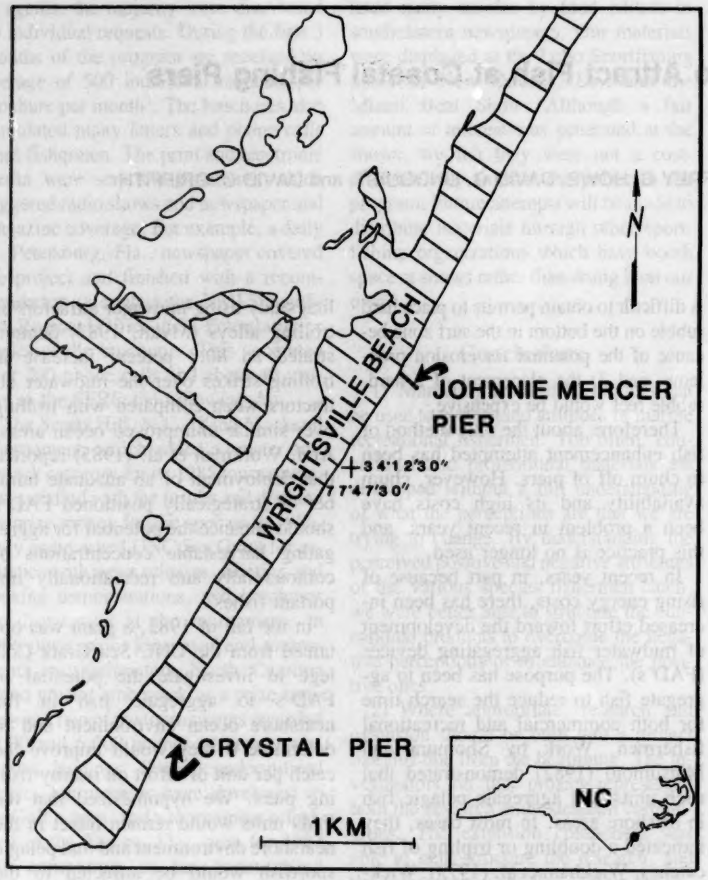

Figure 1.—Study area at Wrightsville Beach, N.C., showing location of the two fishing piers.

ity and similarity of two adjacent fishing piers. One pier was to be FAD-enhanced while the other was to act as a control. Similarity factors included pier length, water depth, seasonality, and fishing restrictions. Two piers at Wrightsville Beach, N.C., Johnnie Mercer's Pier[1] and Crystal Pier, were chosen (Fig. 1).

The study sites were located about 220 m off both piers, which are about 2.5 km apart. Mean depth of the study sites varied from 7 to 10 m; the substratum was primarily sand. Each site was marked off using a spar buoy (115 × 23 cm) at each corner.

Each site consisted of three 100 m long transects (Fig. 2). The north and south transects contained eight concrete-filled tires, two of which anchored the spar buoys. The remaining six anchored the midwater FAD's. The middle transect consisted of six tires for FAD anchoring. All three transect lines were interconnected using 7 mm nylon line. In addition, a 4S Danforth anchor was tied into the end of each 100 m transect for additional stability (Fig. 3, 4).

The anchoring systems were deployed off Johnnie Mercer's Pier on 1 May 1984 and off Crystal Pier on 2 May 1984. Each of the spar buoys was marked to discourage deep trolling, anchoring, and to designate the area as an artificial reef and research area.

The eighteen midwater FAD's used in this study were supplied by McIntosh Marine, Inc., Fort Lauderdale, Fla. Each FAD consisted of four fiberglass rods, 7 mm knotless netting, a PVC nose cone, a large midwater buoy, and four rod buoys (Fig. 5). If properly balanced, the FAD's positioned themselves horizontally in the water column about 4-5 m below the surface (Fig. 2, 5). The 18 FAD's made up the experimental study site. Although the control site was void of any FAD's, a vertical line and large midwater buoy identical to the experimental site (minus the FAD) were deployed on each transect string. This allowed comparisons between the attracting capabilities of the FAD's, to that of the other components of the array.

All 18 FAD's were transported to Crystal Pier on 3 May 1984. Stringing two or three FAD's together, two divers deployed each of the eighteen FAD's. The pier owners were concerned that as the location of the FAD's spread among fishermen, business on the pier void of FAD's would suffer. Consequently, the FAD's were alternated between both piers every 5-6 weeks. Additionally, the surface marker buoys were left off the ends of both piers during the entire period in order to disguise the location of the FAD's to fishermen.

Another potential problem was the loss of fishing gear and/or fish due to entanglement with the FAD's. The pier owners were quite adamant about placing the FAD's far enough away to avoid this. A 750-foot (229 m) location distance from the end of the pier was agreed upon, since some fishermen using float rigs were capable of fishing that far out. Further, North Carolina pier owners have exclusive rights to

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

use of an area 750 feet from the sides and end of their pier. It was theorized that pelagic fish would roam between the perimeter of the units and the pier and be available to catch. This distance may have been unnecessarily restrictive, and will be discussed later.

Pier Survey Procedure

During a 10-week period prior to FAD enhancement (from 1 October to 14 December 1983), pier fishermen were interviewed to obtain catch per unit of effort (CPUE) data on the piers. The purpose was to obtain data to determine whether one pier naturally outfished another and to test the survey instrument. Fishermen were then sampled simultaneously 3 days per week and 3 hours per day from 3 May 1984 to 16 October 1984. The days of the week and the hours of the day were chosen randomly from a random numbers table. Each day was divided into three parts: 0600-1200, 1200-1800, and 1800-2400 hours. Each of the periods was broken into six 1-hour segments, and one time slot for each segment was chosen randomly.

The effective fishing area on each pier was about 229 m. The pier was divided and recorded in three 76 m sections—nearshore, middle, and end. Again, fishermen were interviewed simultaneously at each pier during these times to reduce day, time, and weather variables as much as possible. Attempts were made to interview all fishermen; however, when the pier was too crowded to do so, an equal number of fishermen were chosen from each section of the pier.

The data recorded included the date, time, number of fishermen, number of fishing rods used, wet gear time (minutes × rods used), number and mean weight of fishes caught by species, and weather conditions (i.e., wave height, wind speed and direction, and water temperature). Weight of fish was recorded using a portable 22.68 kg scale. During the 1984 season the survey was continued while both piers were alternately enhanced with FAD's.

Underwater Fish Assessment

Daylight censusing was performed

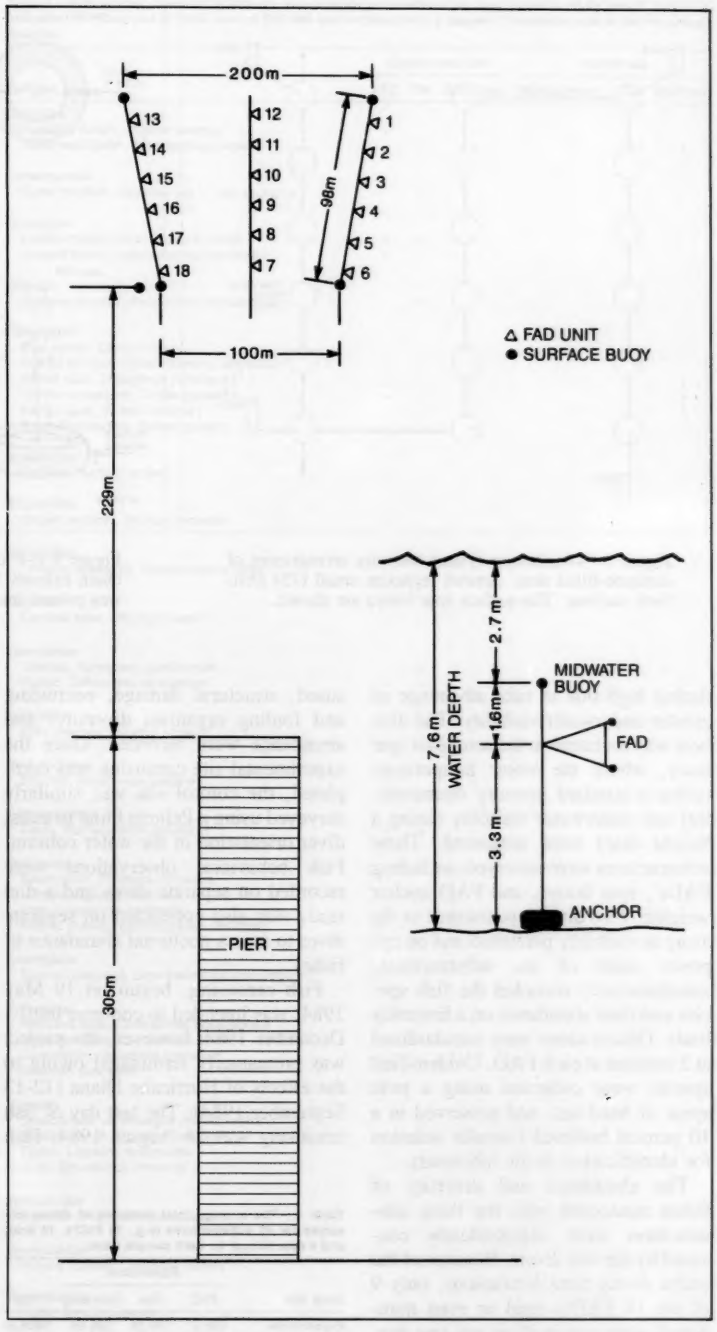

Figure 2.—Configuration of the 18 FAD units near the end of the experimental pier. Inset shows location of FAD in water column.

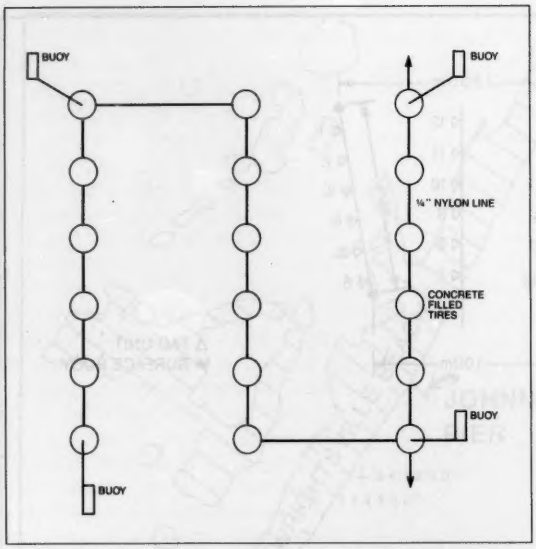

Figure 3.—Anchoring system showing arrangement of concrete-filled tires. Arrows represent small (7S) Danforth anchors. The surface spar buoys are shown.

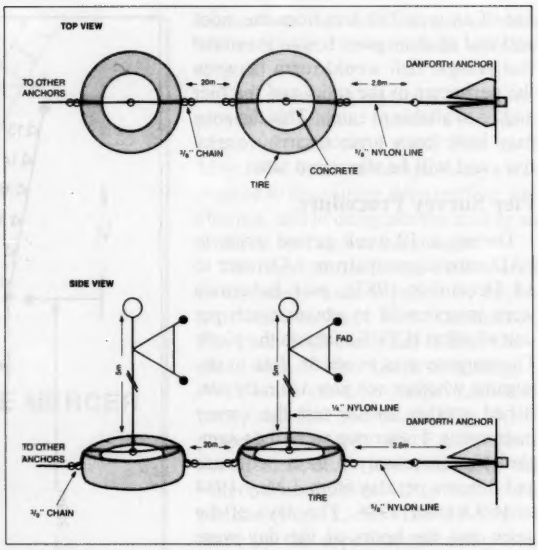

Figure 4.—Close-up of anchoring system. The 9 mm chain extends through the tire (placed before concrete was poured into tire).

during high tide to take advantage of greater underwater visibility. The dive boat was anchored to the southeast spar buoy, where the water temperature (using a standard mercury thermometer) and underwater visibility (using a Secchi disc) were measured. Three substructures were surveyed, including FADs', spar buoys, and FAD anchor weights. Two divers, positioned as far away as visibility permitted and on opposite sides of the substructures, simultaneously recorded the fish species and their abundance on a biweekly basis. Observations were standardized at 2 minutes at each FAD. Unidentified species were collected using a pole spear or hand net, and preserved in a 10 percent buffered formalin solution for identification in the laboratory.

The abundance and diversity of fishes associated with the three substructures were independently censused by the two divers. Because of the scuba diving time restrictions, only 9 of the 18 FAD's (odd or even numbered) were censused on any one day. Hence, all 18 FAD's were censused once a week. After each FAD was censused, structural damage, encrusting and fouling organism diversity, and abundance were recorded. Once the experimental site censusing was completed, the control site was similarly surveyed using a Pelican Float to assist diver orientation in the water column. Fish behavioral observations were recorded on separate dives and a diel study was also conducted on separate dives to assess nocturnal abundance of fishes.

Fish censusing, begun on 19 May 1984, was intended to continue until 1 December 1984; however, the project was prematurely terminated owing to the effects of Hurricane Diana (12-13 September 1984). The last day of fish censusing was 26 August 1984. Fish census data were analyzed using the Statistical Analysis System (SAS), and CPUE data were analyzed with the Statistical Package for the Social Sciences (SPSS) subprogram T-TEST (Nie et al., 1975).

Table 1.—The average total numbers of fishes observed for all substructures (e.g., 18 FAD's, 18 tires, and 4 spar buoys) for each sample week.

	Substructure			
Study site	FAD	Tire	Spar buoy	Total
Experimental	638.67	170.29	595.24	1404.20
Control	0.00[1]	57.78	153.41	211.19

[1]Observations made in the water column corresponding to the location of the experimental FAD.

Results

Underwater Surveys

Throughout the study, each diver made 67 dives, representing a total of 116.55 hours of underwater observation. During 68.19 hours of underwater observation at the experimental site, an average of 1404.20 fishes were observed for three substructures (Table 1). At the control site, an average of 211.19 fishes were observed for the substructures during 21.43 hours of underwater observation (Table 1). The remaining 26.93 hours involved behavioral and diel/nocturnal observations.

The total fish fauna (Table 2) observed at the experimental site included 35 species (21 families and 31 genera). Of the 35 species, 26 species were encountered solely at the FAD's

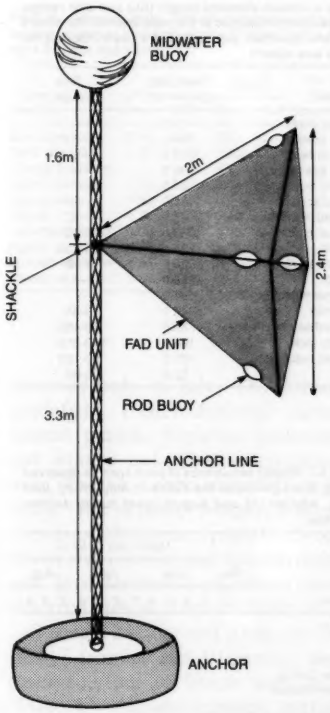

Figure 5.—An individual FAD unit.

during day and night observations (Table 2). Twenty-two species were sighted at the tire anchor weights (Table 2). Thirteen of these species were different from those observed at the FAD's. Species observed at the spar buoys (Table 2) of the experimental site consisted of 14 species.

Blue runners, *Caranx crysos*, and butterfish, *Peprilus triacanthus*, were the most abundant species observed at the FAD's (Table 3). Of the 26 species observed at the FAD's, 10 are considered pelagics, and they represented 79 percent of the mean number of individuals/species observed at the FAD's (Table 3). Three of the 10 pelagics are considered target species or species of prime interest. These species represented 8 percent of the mean number of individuals/species observed at the FAD's (Table 3).

During the study, there was a mean total of 5.76 ± 1.85 species observed

Table 2.—Fish species observed at both the experimental and control sites over the entire study period. A plus (+) indicates fish observed at least once at that site and substructure; a dagger (†) indicates one of the ten pelagic species.

	Experimental site			Control site		
Species	FAD	Tire	Spar buoy	Midwater buoys	Tire	Spar buoy
Balistidae						
Scrawled filefish, *Aluterus scriptus*	+		+			
Planehead filefish, *Monacanthus hispidus*	+	+	+		+	+
Batrachoididae						
Oyster toadfish, *Opsanus tau*		+				
Blenniidae						
Feather blenny, *Hypsoblennius hentzi*	+	+				
Crested blenny, *Hypleurochilus geminatus*[1]	+					
Bothidae						
Summer flounder, *Paralichthys dentatus*		+			+	
Carangidae						
Blue runner, *Caranx cryso*†	+	+	+		+	+
Atlantic bumper, *Chloroscombrus chrysurus*†	+		+			
Round scad, *Decapterus punctatus*†	+	+	+			+
Greater amberjack, *Seriola dumerili*†	+		+			+
Almaco jack, *Seriola rivoliana*†	+		+			+
Banded rudderfish, *Seriola zonata*†	+		+			+
Echeneidae						
Remora, *Remora remora*	+					
Engraulidae						
Striped anchovy, *Anchoa hepsetus*	+					
Ephippidae						
Atlantic spadefish, *Chaetodipterus faber*	+					
Gadidae						
Carolina hake, *Urophycis earlii*[1]	+					
Haemulidae						
Tomtate, *Haemulon aurolineatum*		+			+	
Pigfish, *Orthopristis chrysoptera*	+	+				
Lutjanidae						
Gray snapper, *Lutjanus griseus*[1]	+					
Pomatomidae						
Bluefish, *Pomatomus saltatrix*†	+		+			+
Rachycentridae						
Cobia, *Rachycentron canadum*†	+	+	+			+
Sciaenidae						
Silver perch, *Bairdiella chrysoura*					+	
Cubbyu, *Equetus umbrosus*					+	
Spot, *Leiostomus xanthurus*	+					
Atlantic croaker, *Micropogonias undulatus*		+				
Scombridae						
Spanish mackerel, *Scomberomorus maculatus*†	+					
Serranidae						
Rock sea bass, *Centropristis philadelphica*		+	+			
Black sea bass, *Centropristis striata*	+	+			+	
Sand perch, *Diplectrum formosum*					+	
Unknown post-larva	+					
Sparidae						
Sheepshead, *Archosargus probatocephalus*		+				
Spottail pinfish, *Diplodus holbrooki*	+					
Pinfish, *Lagodon rhomboides*	+	+	+		+	+
Scup, *Stenotomus chrysops*	+	+	+		+	
Stromateidae						
Butterfish, *Peprilus triacanthus*†	+	+			+	
Synodontidae						
Inshore lizardfish, *Synodus foetens*		+			+	
Tetraodontidae						
Puffer, *Sphoeroides* sp.			+			
Triglidae						
Leopard searobin, *Prionotus scitulus*		+	+		+	

[1]Observed at the damaged FAD's during post-Hurricane Diana assessment.

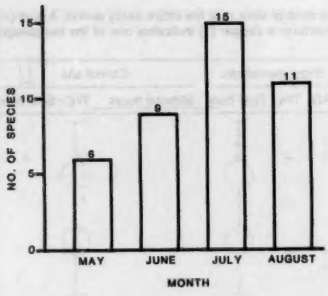

Figure 6.—The total number of fish species observed per month at the experimental site (FAD's only).

per sample day in the experimental site and a mean of 3.67±8.91 individuals for each FAD. A total of six different species were observed in May, and a maximum of 15 species observed in July (Fig. 6). Of the 17 species collected, the mean standard length of the summer flounder, *Paralichthys dentatus*, was the largest (Table 4).

Fishes were not observed in the upper section of the water column, analogous to FAD placement, within the control site (Table 2). Fourteen species were observed at the FAD anchor weights at the control site (Table 2). This was five species fewer than observed at the experimental FAD anchor weights. The fish fauna at the spar buoys at the control site consisted of nine species (Table 2).

Of the 12 species associated with the FAD anchor weights at both the experimental and control sites, the abundance of scup, *Stenotomus chrysops*, and summer flounder was significantly greater at the experimental site. In addition, there was no significant difference in the abundance between the nine species observed at the spar buoys between both the experimental and control sites. Blue runner, the most common species observed at the spar buoys, showed no significant difference in abundance between the spar buoys and FAD's ($P>0.05$ Wilcoxon Rank Sum Test). In all cases, no fishes were associated with the midwater buoy at the control site. Therefore, no statistical analysis was necessary.

Table 3.—Mean number of individuals per FAD for each species observed during dives (n=30) at the FAD's over the entire study period. Species observed during post-Hurricane Diana assessment are not included.

Species	Mean	(SD)	No. of dives observed
Scrawled filefish	1.43	(1.21)	8
Striped anchovy	1.00	(—)	1
Blue runner	12.33	(12.32)	24
Black sea bass	1.59	(1.10)	20
Atlantic spadefish	1.56	(0.88)	4
Atlantic bumper[1]	2.08	(1.00)	6
Round scad[1]	2.98	(2.72)	14
Spottail pinfish	1.17	(0.41)	5
Feather blenny	1.00	(0.00)	1
Pinfish	1.26	(0.61)	22
Spot	1.00	(0.00)	2
Planehead filefish	1.89	(1.68)	21
Pigfish	4.00	(1.15)	4
Bluefish[1,2]	5.33	(5.86)	1
Butterfish[1]	45.69	(137.12)	4
Cobia[1,2]	1.00	(0.00)	1
Remora	1.00	(0.00)	1
Spanish mackerel[1,2]	1.50	(1.00)	2
Greater amberjack[1]	1.00	(—)	1
Almaco jack[1]	1.92	(1.27)	9
Banded rudderfish[1]	1.15	(0.36)	15
Scup	2.00	(0.00)	2
Unknown serranid post larva	1.00	(—)	1

[1]Pelagic species.
[2]Target species.

Water visibility and temperature at the experimental site averaged 4.6 m (range=2.0-7.0 m) and 22.8°C (range=17.2°-25.6°C). There was no significant correlation in the mean number of fishes sighted at the FAD's at varying water visibilities or temperature ($P>0.05$ GLM and ANOVA). In addition, there was no interaction between water visibility and temperature with respect to the mean number of fishes observed at the FAD's ($P>0.05$ GLM).

Initial recruitment of fishes on the FAD's did not occur rapidly. Fishes were observed for the first time after the FAD's had been deployed 1 week. The planehead filefish, *Monacanthus hispidus*; black sea bass, *Centropristis striata*; pinfish, *Lagodon rhomboides*; blue runner, round scad, *Decapterus punctatus*; and the banded rudderfish, *Seriola zonata*, were the only species observed at the FAD's consistently during the study period (Table 5). Blue runner, black sea bass, and pinfish were not initially observed until 5 June 1984. There was no significant difference in the mean number of individuals per sample day, concerning each of the above six species, when observed at the FAD's over the study period ($P>0.05$ GLM and ANOVA).

Table 4.—Mean standard length (SL) and size ranges for specimens collected at the experimental site. Where only one specimen was collected, a dash indicates the range was absent.

Species	Mean size (SL in mm)	Size range (mm)
Striped anchovy	45.0	—
Silver perch	160.0	—
Blue runner	115.0	—
Black sea bass	98.0	—
Atlantic bumper	37.0	—
Round scad	165.0	—
Crested blenny	23.6	11-42
Feather blenny	43.0	20-60
Pinfish	85.0	70-100
Planehead filefish	22.8	17-38
Pigfish	152.0	—
Summer flounder	197.0	—
Butterfish	43.7	43-44
Leopard searobin	85.0	70-100
Almaco jack	145.0	110-215
Banded rudderfish	105.0	60-150
Scup	52.5	45-60

Table 5.—Weekly occurrence of each species observed during dives (n=26) at the FAD's in May (n=2), June (n=8), July (n=11), and August (n=5) during daytime high tide.

	Month and week no.										
	May	June				July				Aug.	
Species	3	1	2	3	4	1	2	3	4	2	3	4
Bluefish	+											
Scup	+											
Butterfish	+	+										
Feather blenny			+									
Scrawled filefish					+	+	+	+	+			
Spot						+			+			
Atlantic spadefish						+						+
Spottail pinfish							+	+	+			+
Remora							+					
Greater amberjack							+					
Almaco jack							+	+	+		+	+
Striped anchovy									+			
Cobia									+			
Atlantic bumper											+	+
Pigfish												+
Spanish mackerel												+
Banded rudderfish	+	+	+	+	+	+	+	+	+			
Planehead filefish	+	+	+	+	+	+	+	+		+	+	+
Round scad	+	+	+				+	+	+		+	+
Blue runner		+		+	+	+	+	+	+	+	+	+
Black sea bass		+	+		+	+	+	+	+	+	+	
Pinfish		+	+	+		+	+	+	+		+	

Scup and bluefish, *Pomatomus saltatrix*, were observed in May through early June (Table 5). The feather blenny, *Hypsoblennius hentzi*, was observed only in mid June (Table 5). The scrawled filefish, *Aluterus scriptus*, was initially observed in mid June through the end of July. Five species, spot, *Leiostomus xanthurus*; remora, *Remora remora*; greater amberjack, *Seriola dumerili*; striped anchovy, *Anchoa hepsetus*; and cobia, *Rachycentron canadum*, were

Table 6.—Mean number (SD) of individuals for each species observed during dives (n=7) at the FAD's during a 24-hour diel study.

Species	Day		Night		No. of dives observed
	$\bar{X}$ no.	(SD)	$\bar{X}$ no.	(SD)	
Blue runner	10.14	(8.2)	9.82	(6.02)	7
Black sea bass	2.41	(1.43)	1.00	(0.00)	7
Atlantic spadefish			1.00	(0.00)	2
Atlantic bumper	1.90	(0.32)	1.00	(—)	5
Round scad	1.50	(0.54)			2
Pinfish	1.22	(0.42)	1.20	(0.44)	6
Planehead filefish	1.00	(0.00)	1.00	(0.00)	7
Pigfish	4.33	(0.82)	2.00	(—)	4
Spanish mackerel	1.50	(1.00)			2
Almaco jack	3.33	(2.10)			2

observed only in July. The Atlantic spadefish, *Chaetodipterus faber*; spottail pinfish, *Diplodus holbrooki*; and almaco jack, *Seriola rivoliana*, were observed in the latter half of the study. The Atlantic bumper, *Chloroscombrus chrysurus*; pigfish, *Orthopristis chrysoptera*; and Spanish mackerel, *Scomberomoros maculatus*, were observed only in August (Table 5).

During a 24-hour diel study, 10 species (7 families and 10 genera) were observed, four of which were jacks (Table 6). Atlantic bumper, pigfish, Atlantic spadefish, and Spanish mackerel were sighted only during the 24-hour diel study. There was no significant difference in the abundance between the 10 species observed during the 24-hour diel study with respect to night and day periods.

Blue runner were not oriented to any specific section of the FAD. Small numbers of 1-35 individuals were commonly observed swimming around the outside of the FAD's, occasionally exiting through the small opening at the nose cone. They appeared to enter the FAD when threatened by larger fish or at the approach of divers. Schools of blue runner were at times intermixed with a few round scad and almaco jack. Blue runner typically remained close to the FAD's, straying only 1-1.5 m away. Many times, however, schools followed the divers from one FAD to another.

Black sea bass were observed in association with the FAD's 2.5 weeks after FAD deployment. They positioned themselves on the FAD netting near the nose cone, and were not observed in pairs or small schools. Several times this species was observed actively grazing on the fouling organisms attached to the FAD netting. No other species was observed inside the FAD when black sea bass were present. On numerous occasions a small school of blue runner would attempt to swim into the FAD, only to suddenly veer away when confronted by the territorial displays (flaring of fins) of black sea bass. Black sea bass were observed ascending the vertical line from the FAD anchor weight, feeding for a few minutes on the underside of the FAD netting and then descending back to the FAD anchor weight by way of the vertical line.

Within two weeks after the FAD's were deployed, fouling organisms and barnacles were found in relatively small numbers on the FAD netting and rod buoys. After 1-1.5 months, the FAD's had a dense growth of encrusting and fouling organisms. Two species of barnacles, *Chthamalus fragilis* and *Balanus amphitrite*, were present on the rod buoys, nose cones, and fiberglass rods. The FAD netting was primarily fouled with hydroids, *Tubularia crocea* and *Pennaria tiarella*, and bryozoans, *Bugula* sp. There were many caridean shrimps, *Hippolyte* sp. and *Palaemonetes* sp., amphipods, *Gammarus* sp.; crested blennies, *Hypleurochilus geminatus*, and spider crabs, *Libinia emarginata*, associated with the netting and fouling organisms.

Butterfish were primarily observed in large schools of 60-200 individuals of varying sizes. Butterfish were usually found swimming near the upper, open-ended section of the FAD, occasionally straying 2-3 m from the FAD. When divers approached butterfish, they moved into the FAD.

Planehead filefish appeared to use the FAD primarily for protection. Solitary or small schools of 1-2 cm specimens hovered very close to the netting located near the fiberglass rods, rod buoys, or the folds of the nylon netting at the mouth of the FAD. Once a dense growth of fouling organisms was present, small individuals were difficult to observe due to their cryptic coloration. Larger individuals (10-15 cm), which were not as abundant, were usually associated with the nose cone. These larger individuals were rarely observed feeding on the fouling organisms attached to the FAD netting and vertical line.

Single individuals or pairs of banded rudderfish were apparently very territorial around the FAD; no other species were observed when they were present. Banded rudderfish actively patrolled the area around the FAD's, investigating and/or chasing off anything (e.g., fishes; jellyfish, *Stomolophus*; divers) that came within close proximity of the FAD. Banded rudderfish strayed as far as 5 m away from the midwater FAD to inspect approaching divers, and appeared fearless of them. While the divers were present, banded rudderfish constantly approached, fled and reapproached the divers while simultaneously altering the intensity of their black bars.

Pinfish appeared to use the FAD's primarily for feeding. Large individuals (10 to 20 cm) pecked and nibbled at the fouling organisms attached to the FAD netting, and those feeding on the inside netting showed aggressive behavior if other species attempted to move inside the FAD. One large pinfish was observed successfully deterring a small school of 10 blue runners.

On rare occasions spadefish and remora were observed near the FAD netting. Spadefish oriented to the underside of the netting, rapidly descending along the vertical line and/or intensifying their black bars when frightened. Remora always hovered below the underside of the netting, which was an expected orientation for this commensal species.

Clearly, the FAD's served many different functions with respect to the various species associated with them. Many of these species also showed strong signs of territoriality, which may have altered the diversity and abundance of fishes associated at each FAD. Objects placed in the midwater column may provide fishes with a visual stimulus for orientation in an otherwise void environment. Each species appears to use the FAD's for different purposes (i.e., orientation, feeding, and protection).

Table 7.—Average number of fish landed per minute of wet gear time. Data for October-December 1983 before FAD deployment.

Species	Pier A[1] (n = 373)	Pier B[1] (n = 616)
Bluefish, *Pomatomus saltatrix*	.0078 (SD = .037)	.0165 (SD = .262) P = .524
King mackerel, *Scomberomorus cavalla*	.0002 (SD = .002)	.0000 (SD = .000) P = .072
Spot, *Leiostomus xanthurus*	.0090 (SD = .073)	.0125 (SD = .069) P = .448
Kingfish,[2] *Menticirrhus* spp.	.0016 (SD = .010)	.0004 (SD = .004) P = .007
Pompano, *Trachinotus* spp.	.0007 (SD = .009)	.0006 (SD = .008) P = .800
Spanish mackerel, *Scomberomorus maculatus*	.0003 (SD = .004)	.0014 (SD = .033) P = .553
Sheepshead, *Archosargus probatocephalus*	.0000 (SD = .000)	.0001 (SD = .002) P = .339
Flounder, *Paralichthys* spp.	.0078 (SD = .100)	.0011 (SD = .009) P = .097

[1]Pier owners preferred that pier names not be associated with CPUE data.
[2]Statistically significant.

Table 8.—Catch data for the two piers during October 1983 before FAD deployment.

Species	Pier A[1] (n = 133)	Pier B[1] (n = 268)
Bluefish, *Pomatomus saltatrix*	.0025 (SD = .013)	.0061 (SD = .061) P = .511
King mackerel,[2] *Scomberomorus cavalla*	.0006 (SD = .003)	.0000 (SD = .000) P = .012
Spot, *Leiostomus xanthurus*	.0164 (SD = .010)	.0189 (SD = .004) P = .781
Kingfish, *Menticirrhus* spp.	.0010 (SD = .001)	.0007 (SD = .000) P = .584
Pompano, *Trachinotus* spp.	.0015 (SD = .001)	.0007 (SD = .006) P = .429
Spanish mackerel,[2] *Scomberomorus maculatus*	.0010 (SD = .007)	.0001 (SD = .001) P = .025
Sheepshead, *Archosargus probatocephalus*	.0000 (SD = .000)	.0000 (SD = .001) P = .331
Flounder, *Paralichthys* spp.	.0175 (SD = .167)	.0010 (SD = .011) P = .109

[1]Pier owners preferred that pier names not be associated with catch data.
[2]Statistically significant.

Midwater FAD Structural Assessment

When the FAD's were initially deployed, the units were positively buoyant and therefore positioned themselves vertically in the water column, with the open end toward the surface. After 2 months, the growth of fouling and encrusting organisms overcame the FAD floatation, causing eight FAD's to sink. At this time, an additional midwater buoy was tied to the FAD which repositioned them vertically.

The weak link of the entire FAD system appeared to lie in the nose cone-fiberglass rod connection. Silicone sealant was recommended as an adhesive, but proved to be inadequate. The loss of four FAD's resulted from the fiberglass rods pulling away from the nose cone. In addition, one fiberglass rod pulled away from the nose cone of four different FADs during the 4-month study. When the FAD's were refitted, the silicone sealant was replaced by PVC cement. This worked well, but is permanent. The FAD's cannot be disassembled without cutting the rods. Additional changes were made in the nose cone shackling system (Murray et al., 1985).

The FAD's nylon netting held up very well. Various kinds of fishing tackle (e.g., down riggers, spoons, monofilament line) were commonly observed entangled within the netting. This tackle in turn produced holdes varying from 2 to 13 cm. Except for the initial tear, holes in the nylon netting did not increase in size from wave action.

Although the study area was spared from the most severe environmental conditions resulting from Hurricane Diana (12-13 September), heavy winds and surge affected the site. An assessment of the aftermath of Hurricane Diana revealed that 8 of the 15 remaining FAD's were missing. Of the eight missing FAD's, five had pulled away from their nose cones, two broke away from the trapeze rings, and the nose cone of one had completely collapsed. The seven remaining FAD's were badly entangled in the FAD netting and vertical FAD line. The nylon netting of these seven units had pulled back away from their nose cones, assuming a collapsed position. In addition, numerous FAD anchor weights were flipped over and/or partially or completely buried in the sediment.

CPUE Survey

Tables 7 through 11 present the results of the CPUE comparisons from Piers A and B. Tables 7 and 8 present CPUE data collected during the fall of 1983, a year before the FAD's were placed off either pier. These comparisons were necessary to determine whether or not higher average catches per unit of effort occurred at either pier under natural conditions. For Table 8, we selected those October 1983 cases because they overlapped in time with the 1984 experimental comparisons shown in Table 11.

For the first two tables, the piers' average CPUE statistics for the eight species were compared using two-tailed T-tests. The probabilities shown demonstrate that few statistically significant differences exist between the two piers. Mean values which are significantly higher, include kingfish for the total (Table 7) and king and Spanish mackerel for the cases within the October time period (Table 8). In these cases, Pier A CPUE averages are higher.

Table 9-11 compare the CPUE statistics from the two piers while using the FAD at one of the piers. Probability levels shown here are computed from one-tailed t-tests, instead of two-tailed. CPUE, however, cannot be less than zero and hence has a skewed, non-normal distribution. Because of this, we transformed CPUE with the formula for the Z-score:

$$\frac{X_i - \bar{X}}{SD}$$

This generated a new variable with a mean of 0 and a standard deviation of 1. The results of the t-tests following these transformations were analyzed for the catches with the FAD at one of the two piers. These transformations did not affect the ultimate findings of the CPUE analysis, which are presented below.

During the first time period (Table 9), while the FAD was anchored off Pier A, significantly more Spanish mackerel were caught per minute of wet gear time from Pier A than from Pier B. However, the CPUE statistics for the two piers during the October 1983 time slot (Table 8) show that Pier A tends to have more

Table 9.—Catch data for the two piers from 3 May 1984 to 14 June 1984 when FAD's were at Pier A.

Species	Pier A (n = 145)	Pier B (n = 174)
Bluefish, *Pomatomus saltatrix*	.0060 (SD = .016)	.0052 (SD = .021) P = .339
King mackerel, *Scomberomorus cavalla*	.0000 (SD = .000)	.0000 (SD = .000) P = .5
Spot, *Leiostomus xanthurus*	.0001 (SD = .001)	.0002 (SD = .001) P = .42
Kingfish, *Menticirrhus* spp.	.0000 (SD = .000)	.0024 (SD = .032) P = .181
Pompano, *Trachinotus* spp.	.0000 (SD = .000)	.0000 (SD = .000) P = .5
Spanish mackerel,[1] *Scomberomorus maculatus*	.0020 (SD = .010)	.0004 (SD = .003) P = .019
Sheepshead, *Archosargus probatocephalus*	.0000 (SD = .000)	.0000 (SD = .000) P = .5
Flounder, *Paralichthys* spp.	.0002 (SD = .002)	.0001 (SD = .001) P = .37

[1]Statistically significant.

Table 10.—Catch data for piers from 17 June 1984 to 30 July 1984 when FAD's were at Pier B.

Species	Pier A (n = 251)	Pier B (n = 360)
Bluefish, *Pomatomus saltatrix*	.0007 (SD = .002)	.0069 (SD = .089) P = .135
King mackerel, *Scomberomorus cavalla*	.0001 (SD = .001)	.0000 (SD = .000) P = .108
Spot, *Leiostomus xanthurus*	.0027 (SD = .018)	.0055 (SD = .028) P = .075
Kingfish, *Menticirrhus* spp.	.0006 (SD = .010)	.0015 (SD = .026) P = .308
Pompano, *Trachinotus* spp.	.0000 (SD = .000)	.0000 (SD = .000) P = .202
Spanish mackerel,[1] *Scomberomorus maculatus*	.0007 (SD = .003)	.0001 (SD = .001) P = .002
Sheepshead, *Archosargus probatocephalus*	.0001 (SD = .001)	.0000 (SD = .000) P = .0115
Flounder, *Paralichthys* spp.	.0012 (SD = .008)	.0014 (SD = .017) P = .45

[1]Statistically significant.

Table 11.—Catch data for piers from 31 July 1984 to 16 October 1984 when FAD's were at Pier A.

Species	Pier A (n = 199)	Pier B (n = 415)
Bluefish, *Pomatomus saltatrix*	.0123 (SD = .080)	.0428 (SD = .018) P = .119
King mackerel, *Scomberomorus cavalla*	.0000 (SD = .000)	.0000 (SD = .000) P = .074
Spot, *Leiostomus xanthurus*	.0266 (SD = .126)	.0487 (SD = .331) P = .181
Kingfish,[1] *Menticirrhus* spp.	.0041 (SD = .040)	.0007 (SD = .006) P = .044
Pompano, *Trachinotus* spp.	.0006 (SD = .003)	.0083 (SD = .069) P = .169
Spanish mackerel, *Scomberomorus maculatus*	.0000 (SD = .000)	.0004 (SD = .007) P = .204
Sheepshead, *Archosargus probatocephalus*	.0001 (SD = .002)	.0000 (SD = .000) P = .118
Flounder, *Paralichthys* spp.	.0002 (SD = .001)	.0120 (SD = .243) P = .247

[1]Statistically significant.

pelagics (king and Spanish mackerel) than Pier B under natural conditions. Table 10 shows that even when the FAD was moved to Pier B from mid-June to July, there were significantly more Spanish mackerel caught from Pier A than from Pier B. The higher CPUE figures for Spanish mackerel at Pier A cannot be attributed to the FAD.

While more Spanish mackerel per unit of effort tend to be caught from Pier A, Pier B CPUE figures for spot and bluefish are higher throughout the summer and autumn months (Tables 10 and 11) than Pier A's figures, although not statistically significant. Finally, Table 11 shows that the kingfish CPUE was significantly higher than Pier A when the FAD's were at Pier A during the third time period. Again, however, we cannot attribute this difference to the presence of the FAD, since significantly more kingfish are caught at Pier A under natural conditions (Table 7). CPUE data were also computed and compared between piers for all species; however, the resulting CPUE values were too low, due to overall poor CPUE at both piers, to be of any use. These findings suggest that the FAD's did not affect CPUE.

Following comparisons of the total samples, we compared various subsamples within the larger sample on the basis of the section of the pier where fishermen were located (end, middle, shore), the wind direction, wave height, and water temperature. Because the FAD's were placed 229 m from the end of the pier, we thought that fishermen fishing from the end of the pier would have the best chance of catching any fish attracted by the FAD's. It would logically follow that comparisons between the end-of-pier cases from the two piers might yield different CPUE results than those for the entire sample.[2] In general, however, comparisons between the end-of-pier subsamples generated results similar to those of the entire sample. For example, Spanish mackerel CPUE figures were significantly higher at Pier A, with or without the FAD, and Pier B still had higher CPUE figures (although not significantly higher) for spot and bluefish.

Nevertheless, there was one important difference between the end-of-pier subsample comparisons and those shown in Tables 8-10. While there were more flounder caught per unit of effort from Pier B for the total sample during the third time period (Table 11—FAD at Pier A), Table 12 shows that the flounder CPUE figures for this time period change significantly when we compare only the end-of-pier subsample values with those presented in Table 8. We can see that

[2]The end-of-pier subsample comparisons are important not only because they support the total sample comparisons, but also because the number of fishermen are more evenly distributed between the two piers, at least during the first two time periods. In Tables 7-11, it is clear that Pier B was used by about twice as many fishermen as Pier A, while significantly higher CPUE statistics almost always favored Pier A. CPUE may be lower at Pier B because there were twice as many fishermen fishing for the same amount of fish, reducing each fisherman's chances by one-half that of Pier A fishermen. However, with the end-of-pier subsample, where the numbers of fishermen were closer to one another, the mean values for CPUE and the significant findings did not radically change, with the exception of flounder.

Table 12.—Catch data for flounder compared for three sample subsets.

Species	Pier A		Pier B	
1983 Sample (without FAD)	.0078 (n = 373)	(SD = .100) P = .097	.0011 (n = 616)	(SD = .262)
31 July - 16 October 1984 Sample (FAD at Pier A)	.0002 (n = 199)	(SD = .001) P = .247	.0120 (n = 415)	(SD = .243)
31 July - 16 October 1984 end-of-pier subsample (FAD at Pier A)	.0002 (n = 115)	(SD = .001) P = .017	.0000 (n = 203)	(SD = .000)

during the same time period a year earlier, under natural conditions, there was no significant difference between the two mean values for flounder.

The increase in flounder with presence of the FAD's may be due to the documented increase in bait fish attracted by the FAD's, instead of a direct causal link between number of flounder and the FAD. However, we present these findings with a note of caution. Although the difference between the two means is not significant, Table 7 shows that the mean value for flounder caught per unit of effort was higher off Pier A during the fall of 1983, under natural conditions.

Finally, selecting out subsamples based on wave height and wind direction did not produce any noticeable departures from the findings presented above. There were a few isolated cases of statistical significance which did not appear in earlier comparisons, but these did not always coincide with the presence or absence of the FAD's. On the basis of the computer analysis in general, we would have to conclude that the FAD's, placed 229 m from the end of the pier, had little if any effect on the anglers' CPUE.

Discussion and Conclusions

In general, the results of the study were mixed. The FAD's proved to be successful in aggregating bait fishes in the nearshore environment. An average of 3.67 ± 8.91 fishes appeared on each FAD, representing 35 different species, in comparison with the control site which had no fishes.

Fish schools attracted to the FAD's during our study were not as large as reported by Klima and Wickham (1971). Reasons for the difference are not clear because the artificial units used in both studies were similar in shape and size and were deployed at a similar depth. The natural habitat of both study sites may have varied greatly. In addition, the rapid recruitment of fishes observed by Klima and Wickham (1971) did not occur in our study. Fishes were not observed until after the FAD's had been deployed for 1 week. This may emphasize the difference between the natural habitats between both studies. Fewer fishes may be present where we deployed the FAD's compared with Klima and Wickham's study site.

Many studies have shown that bottom and midwater artificial reefs increase the CPUE of several pelagic sport fishes (Buchanan et al., 1974; Hammond et al., 1977; Wickham et al., 1973). These studies involved trolling over experimental and control study sites. Unfortunately, trolling was not feasible in our study. Whether or not the CPUE may have been greater at our experimental site concerning pelagic sport fishes using standard trolling methods needs to be investigated. Buchanan (1973), on the other hand, found no significant difference in the CPUE between an artificial reef and the natural habitat for both pelagic and bottom fishes.

The surface areas of an artificial unit and its placement in the water column are important factors governing the diversity and abundance of fishes attracted to it. The aggregation of pelagic fishes near or beneath floating and moored objects is well documented (Gooding and Magnuson, 1967; Hunter and Mitchell, 1966, 1968). A greater abundance and diversity of fishes have been shown to associate with midwater units rather than surface units (Klima and Wickham, 1971). In addition, a greater number of fishes are associated with both simple and complex midwater units than surface structures (Klima and Wickham, 1971). Our results are similar to those of Klima and Wickham (1971); the diversity and abundance of fishes were much greater at the FAD's than at the spar buoys. One exception to this concerns the blue runner which did not exhibit a significant difference in their abundance between the FAD's and spar buoys. The surface area of both the spar buoy and FAD differed greatly which might explain to some extent the difference in the abundance and diversity of fishes observed at each structure.

Wickham and Russell (1974) proposed that fish leave artificial structures at night and that new recruitment occurs daily. Our results show no evidence to support this trend. Due to the frequent diving involved with the 24-hour diel study, it seemed likely that we observed the same fishes at the FAD's rather than new recruits. However, blue runner commonly moved from one FAD to another, using the diver as the attractant. A possible explanation of our results may be linked to the natural habitat where our FAD's were deployed. There was no vertical relief or other structures for the fish to use as spatial references. A substantial migration would have been required of the fish in locating additional structures for orientation purposes (e.g. pier pilings, rock jetty).

The initial attraction of fish to midwater objects probably results from visually detecting the object in an otherwise void environment, providing spatial references (Wickham and Russell, 1974). This theory is supported by our study. Although the fishes were capable of moving beyond sight of the FAD's for a short period of time, they appeared to require almost constant visual contact. Water visibility, however, had no apparent effect on fish abundance in our study. In some instances, the attraction of sport pelagic fish appears to involve specific behavioral mechanisms (Wickham et al., 1973). Our study showed no evidence of any species specific mechansisms.

Territorial behavior may have played an important role in governing the abundance and diversity of fish associated with each FAD. The surface area of each FAD was apparently small enought to enable a single individual, especially banded rudderfish to successfully deter all fish that attempted to approach the FAD. Possibly, if the surface area of the

FAD was increased, territorial behavior may have had less affect on the diversity and abundance of fishes associated with the FAD's.

The simple design of the FADs and their relative ease of employment and retrieval make these units feasible for use by individual fisherman and fishing clubs. It is evident though, that the FAD's do require some maintenance (e.g. adding additional floatation) which can be performed easily by divers. Relatively few pelagic sport fish species were seen by divers. One reason for this may include avoidance behavior of pelagic species near divers, making the fishes difficult to see in waters with limited visibility. Another more likely explanation was the general lack of pelagic sport fishes in nearshore water near Wrightsville Beach, N.C., in the summer of 1984. Supporting this conclusion are the very low CPUE statistics. For example, between 17 June and 30 July 1984, a fisherman would have to fish at Pier A 166.6 hours of wet gear time to catch a king mackerel, 23.8 hours to catch a bluefish, and 23.8 hours to catch a Spanish mackerel. At Pier B, which was FAD enhanced, the same fishermen would wait 2.41 hours to catch a bluefish, 166.6 hours to catch a Spanish mackerel, and he would not have caught a king mackerel.

The FAD units were not successful in improving fishing success at the fishing piers. Factors attributed to the poor showing may include the generally poor fishing conditions in the inshore area during 1984. Usually, the fall fishing season produces far more catches of pelagics on the piers. However, Hurricane Diana effectively interrupted the study on 13 September, which may have caused us to miss this important season. Perhaps most important was the distance the units were placed from the piers (229 m). As described, this was a demand placed on us by the pier owners because of their fear of complaints by fishermen who may have lost gear or fish. It may be unrealistic to expect fishes to move this distance and become accessible for catch by fishermen on the piers. If FAD enhancement is attempted by pier owners in the future, it is recommended that the units be moved closer to the pier to just out of casting distance (perhaps 45 m). Loss of gear problems could be addressed by other methods such as a clearly recognizable buoying system and warning signs placed conspicuously on the piers.

A third objective was to determine whether the FAD units would be durable enough to hold up in the nearshore environment where currents and high energy wave action create more stress on the system. Generally the units performed well. Six of the original 18 units were lost and three were replaced. Four were lost because the fiberglass rods slipped out of the nose cone. The rods were originally glued into the nose cone with a silicone sealant. Using PVC cement worked well and should prevent this problem in the future. A fifth FAD was lost due to fraying of the vertical line at the nose-cone juncture. This problem was solved when the shackle system was substituted. The sixth was lost because of galvanic corrosion. This can be corrected through the proper choice of compatible materials. Eight of the remaining 15 units were lost on 13 September 1984 during Hurricane Diana, a category 2 hurricane with 100 mph sustained winds whose eye passed within 12 miles of the units. Major shoreline damage occurred in theWrightsville Beach area and it was surprising that any of the FAD's survived.

The FAD's were relatively easy to deploy. Once the anchoring system was constructed on land, the 18 units and two anchoring systems were deployed by four people, using a 23-foot outboard in 2 1/2 days. At full retail prices, the total cost of the materials (excluding labor and FAD units) was $2,021. The 1984 price listed for 18 FAD units was $2,304. The manufacturer, however, donated the units to the project. Potentially, other homemade designs could be used. Each of the four surface buoys off each pier had its own schools of bait fish, indicating that a single buoy either floating at or below the surface may be effective in aggregating fishes.

Although permits may be difficult to obtain for placing bottom structure in the nearshore environment because of the potential for causing erosion problems, it appeared that bottom structures will also aggregate fishes. Within weeks after placement each concrete-filled tire had black sea bass located on it. The individual tires had only 10 inches of relief, which indicates that a more substantial structure would be quite successful in attracting black sea bass.

Aside from a FAD's ability or inability to aggregate fises at the pier, a further benefit which should not be overlooked is its marketing potential. Although publicity for the project was not sought, the local media discovered the project and wrote several articles about it. FAD enhancement could be used for advertising and marketing purposes and might improve the competitive position of individual piers.

Further Research

The growth in marine recreational fishing participants has outpaced the growth rate of the U.S. population in recent decades by a factor of 2.5 (Chandler, 1984). As more and more fishermen enter the fishery, fisheries-dependent businessmen and fisheries managers will need to develop new and innovative ways to please their customers or constituents. Future research should continue toward improving fishing at public and private access points such as fishing piers, fishing banks, jetties, and bridges. Some questions which surfaced during this study deserve further scrutiny. They include:

1) Acoustic transmitter tagging of pelagic fishes. As midwater reefs and trolling alleys grow in popularity, more work needs to be done to determine the movement patterns of key target species near the attractors. Such information would help in FAD placement decisions near inshore structures such as piers. It would also assist in spacing decisions for individuals units.

The 18 m spacing distance between the individual FAD units chosen for this study was made by "guesswork". We felt that 7.6 m underwater visibility was the maximum for the area and that fish would move from unit to unit by sight. This was obviously not tested. The mechanism that initially attracts fishes to the FAD's is not known. Sight no doubt plays an important factor, but it is also likely that the low frequency sounds generated by currents impinging upon the midwater

structures may be the initial attraction to fishes (Westenberg, 1953). Sight may play the main role in maintaining fishes in association with the FAD's, but not necessarily in the initial attraction of fishes to FAD's. If the low frequency sounds can be duplicated or synthesized and played back underwater, these artificial sounds might be used as initial enhancement mechanisms for artificial reefs.

2) Other FAD configurations should be tested. The three six-FAD unit strings with the two end strings angled toward the pier were chosen because it was felt the end strings might act as leads toward the pier for fish migrating along the beach. This did not seem to happen because of the distance from the piers. Other designs should be tested.

3) Controlled fishing over the units. Because of time and funding limitations, no attempt was made to use controlled float fishing from boats over the FAD's. Deep troll fishing was prohibited by a special declaration by the Marine Fisheries Commission to avoid boat fishermen taking fish and anchoring over and destroying the units. However, controlled fishing experiments over the units using float or surface trolling methods may be an effective way of determining pelagic fish availability since they may have avoided the divers. Also, a future use for FAD's may be inshore trolling alleys or float fishing areas. Research is needed to determine fishing success by fishing over them.

4) The FAD's we used in the study were chosen because they had been successfully tested in offshore waters, and they were donated for the project. However, experimentation with other midwater designs should be encouraged. Bottom structure in the nearshore zone appears to show promise particularly for black sea bass. Coastal engineers should experiment with designs which can be placed in this environment without causing erosion. One possibility would be to attach the structure to the pier pilings which would be off the bottom and allow for sand transport below it.

5) Several assumptions were made by the pier owners about the motivations of their pier fishermen. A survey of pier fishermen regarding attitudes toward fish enhancement, loss of gear, etc. should be conducted to help pier owners make informed decisions about constructing FAD's for their users.

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An Estimate of Unsurveyed Coastal Recreational Boat Fishing Activity in Texas

MAURY O. FERGUSON and ALBERT W. GREEN

ABSTRACT—The Texas Parks and Wildlife Department has conducted on-site creel surveys to estimate saltwater sportfishing landings and pressure since 1974. Boat trips originating from launch sites such as marina wet slips and boathouses at private residences have not been surveyed and were not included in landings and pressure estimates. In 1982 a mail survey of boat owners registered in Texas was conducted to estimate the percent of saltwater sportfishing boat trips that were missed by the on-site survey and the percent and number of registered Texas boat owners who use their boats for saltwater fishing. From 25 to 30 percent of all saltwater sportfishing boat trips originated from unsurveyed launch sites. Therefore, the TPWD on-site boat survey underestimates saltwater sportfishing boat pressure by 355,000-426,000 trips annually. Of the estimated 79,200 saltwater fishing boat owners, 18 percent never launched from surveyed sites in 1982.

Introduction

Management and allocation of fishery resources requires information on changes in fish populations, the composition of the harvest, and numbers and behavior of fishermen. Since September 1974, the Texas Parks and Wildlife Department (TPWD) has conducted coastwide surveys of saltwater sportfishing in Texas' marine waters to determine minimum estimates of boat, wade-bank, and lighted-pier fishing pressure and landings (McEachron, 1980, 1983; McEachron et al., 1981; McEachron and Green, 1983).

Surveys were conducted during 1979-80 to estimate pressure and landings from specialized fishing activities for fall wade-bank southern flounder, *Paralichthys lethostigma* (Spiller, 1982), fall wade-bank red drum, *Sciaenops ocellatus* (Weixelman, 1982), and spring black drum, *Pogonias cromis* (Campbell-Hostettler, 1982). The coastwide surveys provide information on the majority of saltwater sportfishing activity. However, fishermen launching boats from private residences and some types of marinas are not included in these estimates.

In 1982 a mail survey of boat owners registered in Texas was conducted to estimate the percent of saltwater sportfishing boat trips missed by the on-site survey. Secondary objectives included estimating: 1) The number and percent of registered Texas boat owners participating and boats used in saltwater sportfishing and 2) the total number of saltwater sportfishing boat trips made during 1982. The estimate of the percent of boat trips not sampled could be used to adjust coastwide on-site survey estimates of saltwater sportboat fishing pressure and landings.

Materials and Methods

The TPWD boat registration file was used to sample randomly owners of boats <12 m long with a postcard mail survey six times during 1982. All motorized boats must be registered with TPWD unless hold capacity exceeds 4.5 metric tons. Except for headboats, vessels ≥12 m and vessels with hold capacity >4.5 metric tons that are documented by the U.S. Coast Guard are not normally used for sportfishing (Ditton et al., 1980a).

In December 1981, 100 each of three different preliminary survey questionnaire forms were tested. The questionnaires requested information on boating activity during November 1981 and were evaluated for clarity and response rates. Beginning in March 1982, postcards were mailed first class every other month (bimonthly waves) to selected boat owners. Each wave requested information on the previous month's boating activity. Boat owners were stratified according to residence in coastal and noncoastal counties. Coastal counties were defined as those having any portion of their borders within 80 km of the surf line (Fig. 1). For both coastal and noncoastal counties the first registration record to be sampled was selected from a random numbers table. A unique starting record was chosen for each wave of the survey. The total number of boats <12 m on the registration file was divided by the sample size to determine the interval between sampled records. If a boat owner was selected more than once in a single wave, only the first selection was used.

Sample sizes for each wave were determined using the variance and return rates from the pretest for the first wave and from previous waves for the last five waves ($\alpha = 0.05$, $P = 0.80$) (Sokal and Rohlf, 1981). In January 1983, an additional questionnaire requesting information for the entire year was mailed to determine the percent of boat owners and boats participating in saltwater sportfishing. This final mailing was required because the monthly surveys would have

The authors are with the Texas Parks and Wildlife Department's Coastal Fisheries Branch, 4200 Smith School Road, Austin, TX 78744.

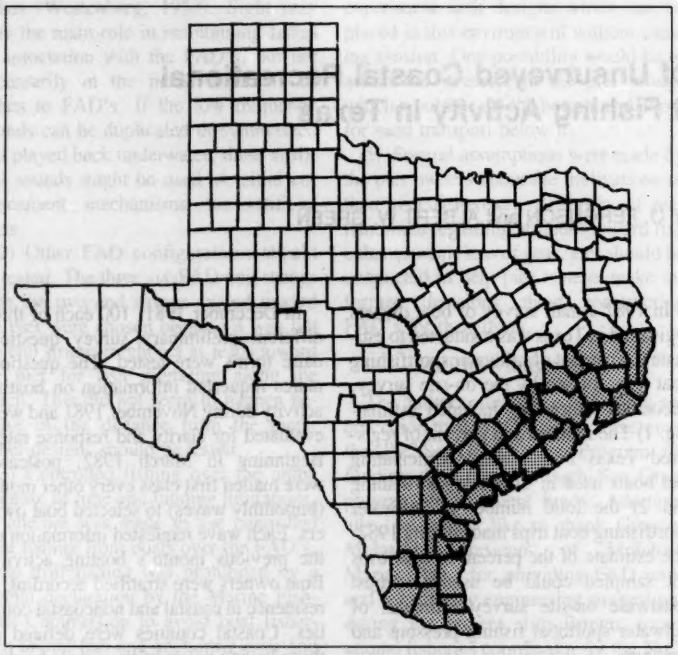

Figure 1.—Texas coastal counties within 80 kilometers of the surf line.

How many boats did you own in **August** 1982? ☐

How many of these boats were registered with Texas Parks and Wildlife (TX No.)?
Note: Any boat not powered by a motor (canoe, sailboat) is not required to be registered ☐

How many **days** was your boat(s) used in Texas during the month of **August**?
If it was not used enter a "0" and return ☐

How many **days** was your boat used in Texas during **August** in:
Fresh water (reservoir, lake, river, pond)_____ Salt water (bay or gulf)?_____

How many **days** was your boat used in the following activities during **August**?
Fishing _____ Skiing_____ Scuba_____ Other?_____

How many **days** was your boat launched during **August**:
From a free public boat ramp? ☐
From a commercial boat ramp (fee required)? ☐
From a boat ramp or boat-house at a private residence? ☐
From a commercial boat-house? ☐
From a ramp at a marina? ☐
From a marina wet slip? ☐
Other than the above? ☐

Explain_____

PWD 399 (Rev. 8/82) 3400

Figure 2.—Final form used to conduct the monthly and annual surveys.

overestimated total boats and boat owners in a year due to possible sampling of the same boat owners in successive waves.

All questionnaires requested boat owners to provide the number of boats owned, the total number of days their boats were used, types of boating activities (i.e., fishing, sailing, pleasure riding), and the total number of launches made from each type of launch site. The types of launch sites were free public boat ramps, commercial boat ramps, boat ramps or boathouses at private residences, commercial boathouses, marinas, and others. Information was requested on all types of salt- and freshwater boating activities to increase interest and, hopefully, to increase the response rates. A question on the number of boats registered with TPWD was asked on a subsample of the first two waves. After determining that response rates were not decreased, this question was included on all questionnaires. During the fourth wave a change in design (Fig. 2) was tested on a subsample of selected boat owners. This revision allowed better matching of activities with area fished and permitted launches from marina boat ramps (which are included in the on-site surveys) to be separated from launches at marina wet slips and dry docks (which are not included in the on-site surveys). The revised questionnaire was used during the rest of the study.

The sample size for each wave varied from 1,400 to 1,700 (Table 1). Sample sizes were highest during fall, winter, and spring when saltwater boat sportfishing activity was low (McEachron, 1979; McEachron et al., 1983) and the probability of encountering fishing for the survey month was low. Sample sizes for inland county boat owners were reduced after the third wave because the low percent of saltwater sport-boat fishing participants and low variances associated with the estimates allowed a true difference among means to be detected with a smaller sample size (Sokal and Rohlf, 1981).

A telephone follow-up was used to determine nonrespondent activity and to clarify ambiguous returns from the first wave. Telephone surveys to obtain nonresponse data were discontinued in subsequent waves because of low success in

Table 1.—Sample sizes (initial mailings) and fate of each survey questionnaire for the six bimonthly waves and final annual wave.

Wave	Area	Sample size	Nondeliverable	Ineligible responses	Adjusted sample size	Useable responses	
						Total	Percent
February	Coastal	850	19	6	825	394	47.8
	Inland	850	17	6	827	435	52.6
	Total	1,700	36	12	1,652	829	50.2
April	Coastal	850	28	18	804	499	62.1
	Inland	850	20	19	811	507	62.5
	Total	1,700	48	37	1,615	1,006	62.3
June	Coastal	700	25	13	662	408	61.6
	Inland	700	15	11	674	407	60.4
	Total	1,400	40	24	1,336	815	61.0
August	Coastal	900	20	15	865	489	56.5
	Inland	700	22	4	674	422	62.6
	Total	1,600	42	19	1,539	911	59.2
October	Coastal	1,100	39	16	1,045	685	65.5
	Inland	600	18	9	573	388	67.7
	Total	1,700	57	25	1,618	1,073	66.3
December	Coastal	1,100	35	20	1,045	716	68.5
	Inland	600	18	9	573	410	71.6
	Total	1,700	53	29	1,618	1,126	69.6
Annual	Coastal	500	20	2	478	283	59.2
	Inland	500	12	3	485	314	64.7
	Total	1,000	32	5	963	597	62.0

contacting nonrespondents. Only 19 of 72 selected nonrespondents were successfully contacted; the remainder could not be found by telephone operators, had unpublished numbers, disconnected phones, or were busy or did not answer on repeated tries.

Beginning with the second wave, identical postcards were mailed to nonrespondents 15 days after the initial mailing. Beginning with the fifth wave, a third set of postcards was mailed to nonrespondents a month after the initial mailing as a further attempt to increase the response rate. Telephone contact was used during all waves to clarify ambiguous returns and to match fishing areas, days, and launches when more than one type of activity occurred. The total useable response rate ranged from 50.2 percent for the February wave to 69.6 percent for the December wave. Secondary mailings increased response rates by 6.3-28.3 percent and third mailings increased response rates by 2.3-6.2 percent. Since the objectives were concerned with sportboat fishing only, returns were defined as ineligible if the respondent no longer owned a boat or was a commercial fisherman.

The percent of saltwater sportfishing boat trips originating from each launch site type was estimated from monthly wave data. Launch sites were categorized into three types: 1) Surveyed (public and commercial boat ramps, and marina boat ramps), 2) unsurveyed (private residences, commercial boathouses, and marina wet slips), and 3) unknown, where it could not be determined whether the site was surveyed or not (beach launchings and others which were not defined). A stepwise discriminant analysis (BMDP7M, Biomed Statistical Program[1]) was used to determine if responses could be assigned to different populations by area of residence (coastal or inland), wave (months), or response type (initial, subsequent mailings, or telephone) based on the frequency with which members of each group launched their boats from different types of sites. Data from the third mailings were excluded since third mailings were used for only two waves. The percent launchings were transformed using arcsine $\sqrt{}$-percent to approximate a normal distribution and prevent variances that are a function of the mean (Sokal and Rohlf, 1981). The data were pooled whenever the analysis indicated no variables could be used to identify groups. The percent launchings by launch site category was calculated as:

$$\hat{L}_c = 100 \frac{\sum_{i=1}^{n} l_{ic}}{\sum_{i=1}^{n} \sum_{c=1}^{3} l_{ic}}$$

where:

$\hat{L}_c$ = percent of saltwater sportfishing boat trip launches originating from category c (surveyed, unsurveyed, unknown),

l_{ic} = number of saltwater sportfishing boat launches made from category c by the ith respondent, and

n = the number of respondents.

Variances were computed using ratio estimation (launches at category c/all launches) (Mendenhall et al., 1971). Launches from unknown site types were classified further as surveyed, unsurveyed, or unknown when comments made by the respondent on the questionnaire made it clear as to which category the launch belonged.

Annual wave data was used to calculate the percent and number of registered boat owners who used their boats to fish in salt water. The percent of boat owners in each area of residence was calculated as:

$$\hat{S}_a = \frac{\sum_{i=1}^{n} S_{ia}}{n_a}$$

where:

$\hat{S}_a$ = the percent of registered boat owners living in area a who used their boats to fish in saltwater,

S_{ia} = 1 if the ith respondent living in area used his boat(s) to fish in salt water or 0 of he did not, and

n_a = the number of respondents from area of residence a.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Variance was computed using the variance of a percent (Mendenhall et al., 1971). The statewide percent was computed by weighting percents for each area of residence by the percent registrations for each area.

The number of registered boat owners participating in saltwater sportboat fishing during calendar year 1982 was calculated with annual data using:

$$\hat{B} = \sum_{a=1}^{2} P_a \frac{\sum_{i=1}^{n} S_{ia}}{\sum_{i=1}^{n} y_{ia}}$$

where:

$\hat{B}$ = the estimated number of boat owners participating in saltwater fishing during 1982,

P_a = the number of boats <12 m on the TPWD registration file in area a (coastal, noncoastal),

S_{ia} = 1 if the ith respondent living in area a fished in salt water or 0 if he did not,

y_{ia} = the number of registered boats owned by the ith respondent living in area a, and

n = the number of respondents.

Variances were calculated using ratio estimation (number of participants/registered boats) (Mendenhall et al., 1971), the variance of a product (Mendenhall et al., 1971), and the variance of a sum (Snedecor and Cochran, 1967).

Estimates of the number of boats used in saltwater fishing, and the total number of saltwater boat-fishing trips made during 1982 were calculated by multiplying the total boats <12 m on the registration file with ratio estimators that had owned boats as the denominator. Therefore, an adjustment factor of owned boats tc registered boats was calculated using:

$$\hat{T}_{x_{aw}} = \frac{\sum_{i=1}^{n} b_{iaw}}{\sum_{i=1}^{n} b_{iaw}}$$

where:

$\hat{T}x_{aw}$ = the ratio of owned boats to registered boats in area a (coastal, noncoastal) and wave w,

b_{iaw} = the number of all boats owned by the ith respondent living in area a from wave w,

y_{iaw} = the number of registered boats owned by the ith respondent living in area a from wave w, and

n = the number of respondents in wave w.

Variances were computed using ratio estimation (owned boats/registered boats) (Mendenhall et al., 1971). Two-way analysis of variance was used to determine if data for all areas of residence, and wave-response type could be pooled.

The number of registered boats used for saltwater sportfishing during calendar year 1982 was calculated with annual data using:

$$\hat{F} = \hat{T}x \sum_{a=1}^{2} P_a \frac{\sum_{i=1}^{n} f_{ia}}{\sum_{i=1}^{n} b_{ia}}$$

where:

$\hat{F}$ = the estimated number of registered boats used for saltwater sportfishing during 1982;

$\hat{T}x$ = the pooled adjustment factor of owned boats to registered boats,

P_a = the number of boats <12 m on the TPWD registration file in area a (coastal, noncoastal),

f_{ia} = the total number of boats owned if the ith respondent living in area a fished in salt water,

b_{ia} = the number of boats owned by the ith respondent living in area a, and

n = the number of respondents.

Variances for boats used/owned boats were calculated using ratio estimation (Mendenhall et al., 1971). The variance for the estimate of number of boats used was computed as the variance of a product (Goodman, 1960) and the variance of a sum (Snedecor and Cochran, 1967).

The mean number of saltwater sportfishing trips per boat was calculated for each wave by area of residence using:

$$\hat{M}_{aw} = \frac{\sum_{i=1}^{n} t_{iaw}}{\sum_{i=1}^{n} b_{iaw}}$$

where:

$\hat{M}_{aw}$ = the mean saltwater sportfishing boat trips per all boats owned in area a and wave w,

t_{iaw} = the number of saltwater sportfishing boat trips made by the ith respondent living in area a for wave w,

b_{iaw} = the number of boats owned by the ith respondent living in area a for wave w, and

n = the total number of respondents from area a in wave w.

All responses were used, regardless of participation in saltwater boat sportfishing, in order to simplify calculations of total trips. Variances were calculated using ratio estimation (saltwater sportfishing boat trips/owned boats) (Mendenhall et al., 1971). These means were tested by area and wave reponse type in a two-way analysis of variance (BMDP7M, Biomed Statistical Program). Log transformation was used to assure variances were independent of the means. Two additional one-way analyses of variance testing means by wave response type within each area were conducted to determine if data should be pooled within an area of residence. The method of Games and Howell (1976) for unplanned comparison among pairs of means when variances are heterogeneous was used to determine which waves could be pooled for the coastal area of residence.

The total number of saltwater sportfishing trips made during 1982 was estimated from monthly wave data as:

$$\hat{TT} = 2 \sum_{a=1}^{2} \sum_{w=1}^{6} P_{aw} \cdot \hat{Tx} \cdot \hat{M}_{aw}$$

where:

$\hat{TT}$ = the estimated total number of saltwater sportfishing boat trips made during 1982,

P_{aw} = the number of boats <12 m on the registration file in area of residence a for wave w,

$\hat{T}_x$ = the pooled adjustment factor of owned boats to registered boats, and

$\hat{M}_{aw}$ = the mean saltwater sportfishing boat trips per boat for area of residence a and wave w.

Mean saltwater sportfishing boat trips per boat (M_{aw}) were pooled means for waves that were similar. It was assumed that the six unsurveyed months had the same mean activity as the six surveyed months. The variance for the total pressure (TT) was calculated as the variance of a product (Goodman, 1960) and the variance of the sums (Snedecor and Cochran, 1967).

Results

Launchings at sites which are not sampled by the coastwide on-site survey accounted for 25.3 percent of all activity, including private residences and marina wet slips. Seventy percent of all saltwater sportfishing boat trips in Texas were initiated from areas which are sampled in the on-site survey by TPWD. It was not possible to determine where 4.4 (±2.8) percent of the launches occurred. Launchings at public and commercial boat ramps accounted for 63.6 percent of the total activity (Fig. 3). Based on comments entered on the questionnaires, telephone clarification, and the separation of marina boat ramps from wet slips, 6.7 (±2.7) percent of all launches occurred at marina boat ramps, which are also sampled. The incidence of trips initiated from the three different launch categories was consistent among areas, waves, and response types ($P>0.05$). Eighty-two percent of the saltwater fishing boat owners launched their boats at least once during 1982 from sites that were included in the TPWD on-site sampling frame.

Information from the annual questionnaire revealed that 37.7 percent of coastal boat owners and 7.3 percent of inland boat owners used their boats for sportfishing in saltwater (Table 2). We estimated that 79,200 boat owners used their boats to fish in saltwater. There were no significant differences in the ratios of owned to registered boats between areas of residence ($F_s = 1.92$; df = 1, 2812; $P<0.05$) or among wave-response type ($F_s = 0.42$; df = 5, 2812; $P>0.05$). Therefore a pooled ratio ($\hat{Tx} = 1.078 \pm 0.013$) was used to calculate the number of saltwater sportfishing boats and the total number of saltwater sportfishing trips during 1982.

The total number of saltwater sportfishing boat trips made by registered boat owners in 1982 was 1,420,000 with a 95 percent confidence interval of 1,360,000 to 1,480,000 (Table 3). For coastal boat owners, mean saltwater fishing trips per boat were calculated using pooled data for the February, April, and December waves (0.221 ± 0.047) and for the June, August, and October waves (0.709 ± 0.089); Table 4). For inland boat owners, a pooled mean using data from all months was used (0.043 ± 0.018). This was done because significant differences in the mean number of saltwater sportfishing trips per boat were found between areas of residence ($F_s = 4.81$; df = 1, 4690; $P<0.05$) and among monthly means for coastal boat owners ($F_s = 8.77$; df = 4, 2599; $P<0.05$). However, no significant differences among monthly means were found for inland boat owners ($F_s = 1.63$, df = 4, 2093, $P > 0.05$).

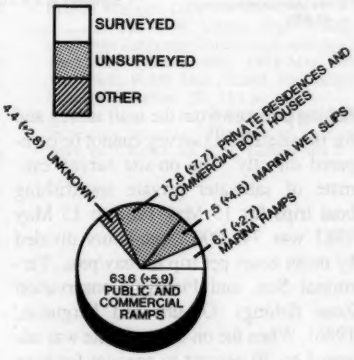

Figure 3.—Percent (±2 SE) of saltwater sport-boat fishing trips originating from surveyed and unsurveyed launch sites and from launch sites where survey coverage was unknown ($n = 571$) during 1982. Surveyed = public, commercial, and marina boat ramps. Unsurveyed = private residences, commercial boat houses, and marine wet slips.

Discussion

The TPWD on-site fishing survey estimates sportfishing boat pressure (in manhours) and landings only for surveyed sites where 70 percent of all trips are initiated. If trip lengths and catch rates are assumed to be similar for surveyed and unsurveyed sites, estimates of pressure and landings should be increased by 30 percent. These assumptions should be tested by conducting intercepts of fishermen on the water when returning to waterfront housing developments, marina wet slips, and commercial boathouses to determine trip lengths and catch rates by species.

Table 2.—Percent (±2 SE) and number (±2 SE) of boats and boat owners participating in saltwater sport-boat fishing during 1982 by area of residence based on results of the annual wave.

Item	Area of Residence		
	Coastal	Inland	Statewide
Boats used			
Percent	43.0 (± 6.2)	10.3 (± 4.1)	21.8 (± 3.4)
Number	87,300 (± 12,600) ± 19,600)	38,900 (± 15,200)	126,000 (
Boat owners			
Percent	37.7 (± 5.8)	7.3 (± 2.9)	18.2 (± 3.5)
Number	59,000 (± 12,700) ± 15,500)	20,200 (± 8,900)	79,200 (

Table 3.—Total number of registered boats < 12 m, adjustment factor of mean owned boats per registered boats (± 2 SE), mean saltwater sportfishing boat trips per owned boat (± 2 SE), and total estimated saltwater sportfishing boat trips (± 2 SE) by area and wave for 1982.

Area	Wave	No. registered boats	Mean saltwater fishing trips per all boats (± 2 SE)	Estimated trips for all boats (± 2 SE)[1]
Coastal	February	198,952	0.221 (± 0.047)	47,400 (± 10,200)
	April	200,372	0.221 (± 0.047)	47,700 (± 10,200)
	June	201,135	0.709 (± 0.089)	154,000 (± 19,400)
	August	203,093	0.709 (± 0.089)	155,000 (± 19,600)
	October	204,226	0.709 (± 0.089)	156,000 (± 19,700)
	December	202,895	0.221 (± 0.047)	44,800 (± 10,400)
	Total for 6 months			605,000 (± 38,200)
	Total for 12 months			1,210,000 (± 54,100)
Inland	February	363,493	0.043 (± 0.018)	16,800 (± 7,060)
	April	365,471	0.043 (± 0.018)	16,900 (± 7,090)
	June	360,009	0.043 (± 0.018)	16,700 (± 6,990)
	August	374,795	0.043 (± 0.018)	17,400 (± 7,270)
	October	375,815	0.043 (± 0.018)	17,400 (± 7,290)
	December	375,819	0.043 (± 0.018)	17,400 (± 7,290)
	Total for 6 months			103,000 (± 17,600)
	Total for 12 months			206,000 (± 24,800)
Statewide Total				1,420,000 (± 59,500)

[1]The ratio of total boats owned/registered boats (1.078 ± 0.013) has been incorporated as a product in these estimates (i.e., 198,952 × 0.221 × 1.078 = 47,400).

Table 4.—Results of the approximate test of equality of monthly mean saltwater sportfishing trips per boat for coastal respondents where variances are heterogeneous. Unplanned comparison among pairs of means using the Games and Howell Method.

Samples (a=6)	n	$\bar{Y}_i$	S_i^2	$S_{\bar{Y}_i}^2 = \frac{S_i^2}{n_i}$	$\frac{\left(S_{\bar{Y}_i}^2\right)^2}{(n_i - 1)}$
February	394	0.175	0.0028	0.0000071	0.000,000,018,1
April	499	0.219	0.0019	0.0000038	0.000,000,007,6
December	716	0.248	0.0010	0.0000013	0.000,000,001,8
June	408	0.634	0.0053	0.0000129	0.000,000,031,7
October	685	0.639	0.0038	0.0000055	0.000,000,008,2
August	489	0.857	0.0089	0.0000182	0.000,000,037,3

Differences among pairs of means ($\bar{Y}_i - \bar{Y}_j$) are below the diagonal and corresponding MSD_{ij} values are above the diagonal.

	February	April	December	June	October	August
February	0	0.150	0.132	0.203	0.162	0.228
April	0.044	0	0.103	0.685	0.139	0.213
December	0.073	0.029	0	0.171	0.119	0.200
June	0.459*	0.415*	0.386*	0	0.195	0.253
October	0.464*	0.420*	0.391*	0.005	0	0.221
August	0.682*	0.638*	0.609*	0.223	0.218	0

* = Significant at $\alpha = 0.05$.

Complete representation of the total population in a survey is difficult. Good statistical design can reduce the level of uncertainty about survey estimates by keeping the nonresponse rate low. This survey had a relatively low nonresponse rate; however, follow-up telephoning to determine nonresponse bias was unsuccessful. Boat registration renewal in Texas is done every 3 years; therefore, a portion of the registration file was probably not accurate due to people moving, dieing, or selling their boats. In a mail survey of Galveston Bay area boat owners, Ditton et al. (1980b) found no significant difference in the frequency of fishing participation (trips made) between respondents and nonrespondents, although nonrespondents were more likely to have sold or stopped using their boats or they may have fished more in fresh water. If nonresponse in this survey was due to inaccuracies in the sampling frame, then the total trips made, boat owners fishing, and boats used in saltwater were overestimated. Estimates from this mail survey were equal to or lower than estimates of other survey (Ditton and Graefe, 1978; Ditton et al., 1980b; Anonymous, 1982; Ditton and Fedler, 1983; NMFS, 1985).

Because of differences in sampling periods and exclusions in sampling frames, estimates of total saltwater sportboat fishing pressure from the mail survey and the on-site TPWD survey cannot be compared directly. The on-site survey estimate of saltwater private sportfishing boat trips for 15 May 1982 to 15 May 1983 was 748,000 (man-hours divided by mean hours per trip for bay/pass, Territorial Sea, and Fishery Conservation Zone fishing) (Osburn and Ferguson, 1986). When the on-site estimate was adjusted by 30 percent to account for trips from unsurveyed sites (approximate 95 percent confidence interval = 935,000 to 1,247,000) it was still less than the lower confidence limit of 1,360,000 trips estimated by the mail survey. This was not surprising, considering the differences between the two surveys. The mail survey did not estimate saltwater sportfishing boat trips made by nonresidents; however, <10 percent of all fishermen interviewed in the on-site survey were nonresidents (Osburn and Ferguson, 1986). The on-site survey did not estimate trips made from access points in Sabine Lake or trips made at night.

There are other surveys that estimate saltwater fishing activity in Texas, but they are not comparable to this mail survey. The National Marine Fisheries Service (NMFS, 1985) estimated that 4,356,000 saltwater fishing trips were made by Texas residents during 1982; however, trips by fishing mode within states were not published. A mail survey conducted by the Texas State Department of Highways and Public Transportation (Anonymous, 1982) estimated that 1,922,400 saltwater sportfishing boat trips were made in Texas during 1982; no variances were available. Recall period was for 1 year of activity, and fishermen >322 km from the coast were not surveyed, which may have resulted in overestimation.

This survey estimated that 38 percent of coastal boat owners, 7 percent of inland boat owners and 18 percent of all boat owners statewide used their boats to fish in saltwater. Ditton and Graefe (1978) and Ditton et al. (1980b) found that 34 percent and 31 percent, respectively, of the boat owners residing around Galveston Bay used their boats for saltwater fishing. Ditton and Fedler (1983) found that 31 percent of coastal boat owners in Texas (within 161 km of the coast) and 4 percent of inland boat owners fished in saltwater. The Texas State Department of Highways and Public Transportation (Anonymous, 1982) survey estimated that 39 percent of all boat owners residing within 322 km of the coast used their boats to fish in saltwater.

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Business Turnover in the Texas Charter Fishing Industry, 1975-85

ROBERT B. DITTON and JEFFREY D. VIZE

ABSTRACT—This is a continuation of a previous study of Texas charter boat industry turnover and stability by Ditton and Loomis published in 1985 in the Marine Fisheries Review, *47(1):43-47. This paper follows the guidelines used in the previous study and continues the temporal analysis of the charter fishing industry using a third inventory to analyze turnover and stability between 1975 and 1985. Comparing the study findings from 1980 to 1985 with those from 1975 to 1980, shows that the Texas charter fishing industry continues to have high turnover rates and overall instability. Of the original 1975 population of charter boat operators, only 25 percent were in operation during 1985. In addition to a more complete understanding of the Texas charter fishing industry, this paper presents an approach which can be used elsewhere to understand charter industry trends.*

Introduction

In a previous study of turnover in the Texas charter boat fishing industry between 1975 and 1980, Ditton and Loomis (1985) found a high turnover rate relative to other types of small business. The charter business climate was characterized by high levels of competition and low profit margins. It was reasoned that entrepeneurs entering the charter business were not oriented to the harsh business climate that existed. Due to the high turnover rate, Ditton and Loomis (1985) determined the Texas charter fishing industry consisted mostly of inexperienced operators. Sixty-five percent of the charter businesses they inventoried were in operation for ≥5 years.

Data on exit and entry rates (turnover) have practical as well as theoretical utility. They help identify causes of charter boat business failures and can be used as economic indicators for the charter fishing industry (Cochran, 1981). This paper provides information useful to understanding regional turnover rates in the Texas charter fishing industry. Starr (1979) acknowledged that there is a paucity of reliable information on the number, size, and growth trends in the small business sector. Cochran (1981) felt such information was valuable to accurately evaluate regulatory impacts to prevent mortalities among small businesses.

This paper extends the temporal analysis of business turnover in the Texas charter fishing industry during 1975-80 (Ditton and Loomis, 1985) with data from a second 5-year study period, 1980-85, to document any further turnover or instability.

Methods

An inventory of charter boat fishing businesses operating along the Texas coast in 1985 was compiled with the same methods used in the 1975 inventory (Ditton et al.[1]) and the 1980 inventory (Matheusik[2]). The criteria used to define a charter fishing boat business are:

1) The charter business operates a vessel that is U.S. Coast Guard certified if it is >5 gross tons. If the vessel is <5 gross tons, the operator is only required to have a Coast Guard motorboat operator's license.

2) The business provides the services of a boat and/or services of a U.S. Coast Guard licensed captain to take ≤6 people fishing (either bay and/or Gulf) for monetary remuneration.

3) The business utilizes a formal advertising method such as the classified section of telephone directories, radio, television, newspapers, magazines, brochures, or an established chartering service.

Using these criteria, the 1975 and 1980 inventories identified 88 and 122 charter boat fishing businesses, respectively. The 1985 inventory identified 117 charter boat businesses operating along the Texas coast. In each inventory the businesses were grouped into five regions: Freeport, Port O'Connor, Rockport, Port Aransas, and South Padre Island.

To examine the extent of change and/or stability in the Texas charter fishing industry, the 1975, 1980, and 1985 populations of charter boat businesses were categorized into subpopulations as appropriate (new, steadfast, new steadfast, continuing steadfast, and dropout businesses).

New businesses are those which entered the market after the 1975 and 1980 inventories were compiled, respectively. The steadfast subpopulation includes

[1]Ditton, R. B., R. N. Jarman, T. J. Mertens, N. P. Schwartz, and S. A. Woods. 1977. Charter fishing on the Texas coast. Unpubl. rep. submitted to Tex. A&M Univ. Sea Grant Coll. Program, Coll. Sta., 186 p.

[2]Matheusik, R. E. 1980. An exploratory analysis of the extent of stability and the characteristics of change in the charterboat industry on the Texas Gulf coast. Unpubl. rep., Dep. Rec. Parks, Tex. A&M Univ., Coll. Sta., 42 p.

The authors are with the Texas Agricultural Experiment Station, Department of Recreation and Parks, Texas A&M University, College Station, TX 77843.

Table 1.—Turnover in the Texas charter fishing industry by region, 1975-85.

Region	1975 Population (a)[4]	Drop-outs (b)	Stead-fast (c)	New population (d)	1980 Population (e)[5,6]	Drop-outs (f)	New[8] steadfast (g)	Continuing[3] steadfast (h)	New population (i)	1985 Population (j)[7]	Net change[1] 1980 – 1975	1985 – 1980	1985 – 1975
Freeport	27	17	10	19[2]	29[2]	20	6	3	12	21	+ 2[2]	– 8	– 6
Port O'Connor	8	1	7	3	10	4	3	3	13	19	+ 2	+ 9	+ 11
Rockport	13	4	9	7	16	4	6	6	4	16	+ 3	0	+ 3
Port Aransas	30	21	9	31	40	21	14	5	10	29	+ 10	– 11	– 1
South Padre	10	3	7	20	27	12	10	5	17	32	+ 17	+ 5	+ 22
Total	88	46	42	80	122	61	39	22	56	117	+ 34	– 5	+ 29

[1]Net change = Businesses operating in 1980 minus businesses operating in 1975, 1985 minus 1980, and 1985 minus 1975.
[2]Column g includes those businesses from column d which were still in operation 1985.
[3]Column h includes those businesses from column c which were still in operation 1985.
[4]a = b + c.
[5]e = c + d.
[6]e = f + g + h.
[7]j = g + h + i.
[8]Denotes correction of data previously reported by Ditton and Loomis (1985).

Table 2.—Turnover in the Texas charter fishing industry along the Texas Gulf coast.

Year	Total businesses	Dropouts (1975-80)	Steadfast (1975-80)
1975	88	46 (52%)	42 (48%)
		New businesses (1975-80)	Steadfast (1975-80)
		80 (66%)	42 (34%)
Year	Total businesses		
1980	122		
		Dropouts (1980-85)	Steadfast (1980-85)
		61 (50%)	61 (50%)
		New businesses (1980-85)	Steadfast (1980-85)
Year	Total businesses		
1985	117	56 (48%)	61 (52%)

Table 3.—Percent change in charter business subpopulations by regions.

Region	New steadfast businesses: Percent of 1980 pop.	New steadfast businesses: Percent of 1985 pop.	Continuing steadfast businesses: Percent of 1975 pop.	Continuing steadfast businesses: Percent of 1985 pop.	Dropout businesses (Percent of 1980 pop.)	New businesses (Percent of 1985 pop.)
Freeport	21	29	11	14	69	57
Port O'Connor	30	16	38	16	40	68
Rockport	38	38	46	38	25	25
Port Aransas	35	48	17	17	53	34
South Padre	37	31	5	16	44	53

those operators identified in 1975 who were still in business during the 1980 inventory. The new steadfast subpopulation consisted of those charter boat businesses identified as new businesses in the 1980 inventory and still operating in 1985. Continuing steadfast businesses included those identified in 1975, reported as steadfast in 1980, and still in operation during the 1985 inventory. The dropout subpopulation is composed of those charter operators that exited the industry after the 1975 and 1980 inventories were completed. Cross-sectional comparisons of the regional subpopulations inventoried in 1975, 1980, and 1985 indicate the rate of turnover, or the relative temporal instability of the Texas charter boat fishing industry. In this paper we examine the extent of stability in the industry between 1980 and 1985, and overall between 1975 and 1985.

Results

The size and distribution of the charter fleet along the Texas coast has changed between 1975 and 1985 (Table 1). In contrast with the growth in number of businesses between 1975 and 1980, five fewer businesses were operating in 1985 than 1980. Net change in the number of charter businesses between 1980 and 1985 varied by region. Nevertheless, 29 more businesses were operating in 1985 than in 1975, a 33 percent increase.

Table 1 shows that of the charter fishing businesses operating in 1980, 61 (50 percent) dropped out of (exited) business by 1985. This rate is similar to that for the previous 5-year period (52 percent). Fifty-six (48 percent) of the 117 businesses operating in 1985 were new (entered) since 1980. This is lower than in the previous 5-year period when 80 new businesses entered the market. Sixty-one (50 percent) of the businesses (new steadfast and continuing steadfast subpopulation combined) operating in 1980 were still operating in 1985. This is about the same percentage of steadfast businesses in the previous 5-year period (48 percent). Of the original 1975 population of charter fishing businesses, only 22 remained (continuing steadfast) in business in 1985 (25 percent) (Tables 1, 2).

The percentage of new steadfast, continuing steadfast, dropout, and new subpopulations differed by region (Table 3). The regions with the two highest dropout rates were Freeport and Port Aransas, respectively. These results are similar to those from the previous 5-year period. The dropout rate for Port Aransas between 1980 and 1985 (53 percent) was less than during 1975-80 (70 percent).

Whereas the number of new entrants exceeded dropouts between 1975 and 1980 inFreeport and Port Aransas, this pattern was reversed between 1980 and 1985.

As with the previous 5-year period there were three regions where new entrants accounted for a majority of the 1985 population. In Port Aransas and Freeport this was due to a high dropout rate. The South Padre Island region continued to have a low dropout rate and a high entry rate. Port O'Connor experienced steady growth in both 5-year study periods. Rockport stands out for its stability with a low percentage of dropouts and new businesses. Six of the nine businesses operating in 1975 were still operating in 1985. Of the seven new businesses between 1975 and 1980, six were still in business in 1985. Although the Rockport region had the highest percentage of steadfast businesses between 1980 and 1985 and the highest percentage of continuing steadfast businesses (taken as a percentage of the 1985 population) (Table 3), the number of continuing steadfast businesses were fairly evenly distributed over the five regions (Table 1).

Discussion

According to Small Business Administration figures SBA (1985), the nation's small businesses have experienced strong economic growth recently. This is not true for the Texas charter boat fishing industry. This paper shows that the Texas charter fishing business continues to be a high-turnover industry.

Two explanations are offered for the high turnover: 1) Increased operating costs for fuel and insurance, and 2) regulatory effects of fisheries management. Operating costs include variable expenses (fuel, wages, bait, ice, tackle) and fixed expenses (insurance, depreciation, dock fees, repairs). Fixed operating costs for charter boat operators do not vary with the extent of charter business. Over two-thirds (70.4 percent) of a Texas charter operator's total business expenses are for variable operating costs (Ditton et al., 1978). Fuel costs for the Texas charter boat fleet have been about 22 percent of total operating expenses (Ditton et al., 1978). Elsewhere, fuel costs have ranged between 17 and 32 percent of total operating expenses, (Browder et al., 1981; Marshall and Lucy, 1981; and Thursland et al., 1982).

The cost of fuel on the coast has varied greatly over the 10-year study period (Table 4). Between 1975 and 1979 the price of both gasoline and diesel fuel remained fairly constant. This may partially account for the positive growth in charter operators in every region for the first 5-year period. Between 1979 and 1981 both diesel and regular fuel prices increased sharply. Between 1979 and 1981, there was a 66 and 66.7 percent increase, respectively, in the standardized price of diesel fuel and regular gasoline. The high price of regular gasoline and diesel fuel may have acted as a deterrent to prospective charter operators and also may have forced several operators to exit the industry.

In 1975 insurance was 8 percent of a charter operator's total operating costs in Texas (Ditton et al., 1978). Likewise, charter insurance costs have ranged between 4 percent and 10 percent elsewhere, (Thursland et al., 1982; Marshall and Lucy, 1981; Browder et al., 1981). Recently, insurance underwriting and availability has become a major concern in the maritime industry, especially for charter boats (Anonymous, 1985).

During the last 4 years there has been a trend toward "uninsurability" for charter boat operators nationwide (Habicht[3]). The charter business is considered a high-risk operation due to the relative inexperience of its customers and the environment in which it operates. With the size of liability awards for bodily injury rising dramatically and the number of claims increasing, marine insurance companies are wary of underwriting charter fishing operators. For example, no gas powered boat over 10 years old and valued at less than $50,000 will be underwritten. For a diesel-powered plastic hull vessel less than 10 years old, insurance would be a minimum of 3 percent of the boat value for $100,000 of basic hull coverage (Habicht[3]). The uninsurability of charter boats can act as a barrier to prospective charter operators entering the business as well as a major reason current operators exit the market.

Fishery regulations and management plans stemming from the Magnuson Fishery Conservation and Management Act of 1976 (16 USC 1801-1882) may also play a role in the turnover of charter operators on the Texas coast. For example, regulations are currently in effect for the mackerel fishery in the Gulf of Mexico. The Fisheries Management Plan (FMP) for Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic (50 CFR 642) establishes catch limitations for king mackerel. Following public hearings and procedures pursuant to the Magnuson Act, the catch limitations became effective on 22 December, 1985. Bag limits of two fish per passenger or three fish per passenger excluding the captain and crew were established for charter operators in Federal and state jurisdictions in the Gulf of Mexico (50 CFR 642). Furthermore, as of January 1986 all charter boat operators that target coastal pelagic species are required to report catch and effort data on each trip using log books to be returned to the National Marine Fisheries Service. Currently, it is proposed that all charter boats which target coastal pelagic species must have a permit from the National Marine Fisheries Service[4].

Although most of these regulations were enacted only recently, they may nevertheless have had an effect on

Table 4.—Annual coastal fuel prices for regular gasoline and diesel, 1975-85 in cents. Data source: Joyce Poole, American Automobile Association, Houston, Tex., March 1986.

Year	Regular gasoline		Diesel	
	Price (¢)	Price standardized to 1975[1]	Price (¢)	Price standardized to 1975[1]
1975	54.8	54.8	NA	NA
1976	53.6	50.7	53.3	50.4
1977	60.5	53.7	57.4	51.0
1978	54.7	45.1	53.7	44.3
1979	65.2	48.3	63.6	47.2
1980	99.8	65.2	105.1	68.7
1981	122.3	72.4	120.8	71.5
1982	118.3	66.0	130.3	72.7
1983	106.6	57.6	121.5	65.6
1984	106.9	55.4	115.6	60.0
1985	99.1	49.6	116.2	58.1

$$^{1}\text{CPI (75)} = \frac{\text{CPI (1975, 1976. . . to 1985)}}{\text{CPI (1975)}} \times 100.$$

$$\text{Standardization} = \frac{\text{Gas price (1975, 1976. . . to 1985)}}{\text{CPI (75)}} \times 100.$$

[3]Habicht, M. 1986. Telephone interview with the President of Maritime Insurance Group, Inc., 2500 Hollywood Blvd., Suite 414, Hollywood, FL 33020, 28 April 1986.

turnover observed in the Texas charter fishing industry. The Fisheries Management Plan and resultant regulations were discussed as early as 1979. The regulations as proposed could have acted as a disincentive for prospective operators. Also, operators might have anticipated the future effects of the regulations and the management plan on their already stressed businesses and exited the industry.

Future Research Needs

Up to this point, entries and exits to the Texas charter fishing industry have been evaluated every 5 years. There are problems with this in that an operator remaining in business for $4\frac{1}{2}$ years and one remaining in business for $4\frac{1}{2}$ months can both be categorized as dropouts. To evaluate business turnover in the charter fleet effectively, it will be necessary to do so on an annual basis. This is now possible in the southeastern United States where the National Marine Fisheries Service's Southeast Fisheries Center conducts an annual canvas of commercial passenger carrying vessels. The categories of vessels included are: 1) Charter fishing boats, 2) head (or party) boats, 3) guide boats, and 4) charter dive boats.

Furthermore, there is a need to conduct follow-up open-ended interviews with new entrants and dropouts regarding their detailed reasons for entering and exiting the industry, respectively. With this information, marine advisory personnel can educate against unrealistic business expectations. Likewise, interviews can help us to understand the extent to which the hypothesized reasons are responsible for the turnover trends observed over the 1975-85 study period.

[4]Draft. Amendment number 2 and environmental assessment and supplemental regulatory impact review and initial regulatory flexibility analysis to the Fishery Management Plan for the coastal migratory pelagic resources. 1986. Gulf of Mexico Fishery Management Council, Lincoln Center, Suite 881, 5401 West Kennedy Blvd., Tampa, FL 33609, and South Atlantic Fishery Management Council, Southpark Building, Suite 306, 1 Southpark Circle, Charleston, SC 29407.

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United States Marine Recreational Fisheries, 1986

Introduction

The National Marine Fisheries Service initiated a series of surveys in 1979 to obtain estimates of participation, catch, and effort by recreational fishermen in the marine waters of the United States. This effort implements the first priority of the NMFS Marine Recreational Fisheries Policy which was established in 1981, namely, the development on a regular and continuing basis of a comprehensive marine recreational fisheries data acquisition and analysis system. The Marine Recreational Fishery Statistics Surveys (MRFSS) have included the use of commercial contractors to perform data collection and processing tasks.

This article[1] covers the MRFSS activities on the Pacific, Atlantic, and Gulf coasts from January through December 1986. The results of the 1979-85 surveys were previously published in the Current Fisheries Statistics publications 8322, 8323, 8324, 8325, 8326, 8327, and 8328.

Data on commercial fisheries have long been collected by the NMFS and its predecessor agencies. However, data on marine recreational fisheries have been collected on a systematic or continuing basis. The purpose of the MRFSS is to establish a reliable data base for estimating the impact of marine recreational fishing on marine resources. The information required for fishery management and development purposes includes size of catch by species, by subregion, by area, and by mode of fishing. For example, the MRFSS helps meet the goals of the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA—Public Law 94-265). The MFCMA mandated a national program for management of fishery resources in the Exclusive Economic Zone (3-200 miles), and requires that the fishery management plans developed consider recreational as well as commercial fisheries and their harvests.

The surveys reported here reflect trip and catch data acquired during 1986, and present a brief summary of the survey findings and results.

These limited data are only a summary of those available from the MRFSS data base. Depending on sample size, catch estimates for individual species at the state, mode, area, and wave levels may be available. Estimates of number of trips and participants are also available at similar levels of detail. Other data available in a variety of formats include catch rates, lengths, weights and site descriptions. Inquiries for additional information should be directed to the NMFS National Fishery Statistics Program, F/RE1, Washington, DC 20235.

Overall Atlantic and Gulf Results

The total number of fish caught in 1986 along the Atlantic and Gulf coasts was estimated at 411.2 million fish (Table 1). This was slightly higher than the 1979-85 average catch of 387.5 million fish. About 37 percent of the total catch was released alive in 1986. However, the percentage of live releases varied considerably among the subregions with 43 percent being released alive in the Gulf of Mexico subregion, 36 percent in the Middle Atlantic, 35 percent in the South Atlantic, and 25 percent in the North Atlantic subregion. Overall, the total Atlantic and Gulf estimates are very consistent with previous survey years.

The 1986 catch did show some significant changes from 1979 to 1985 in the total number of fish caught in some important species groups. Black sea bass and scup catches in 1986 were more than double the 1979-85 average catches, while winter flounder catches in 1986 were less than half of the 1979-85 levels. Bluefish, spot, Atlantic croaker, summer flounder, winter flounder, spotted seatrout and black sea bass remained the most frequently caught species. Bluefish, which ranked either first or second in number caught in 1979-85, was ranked third after black sea bass and Atlantic croaker in 1986.

Over 80 percent of the catch in number of fish was taken in inland waters (e.g., rivers, sounds, bays) or in the ocean within 3 miles of shore in 1986. About 16 percent of the catch was taken in waters >3 miles from shore. The remaining portion of the catch could not be identified by area. The proportion of the 1986 catch in number taken in waters >3 miles from shore varied from 7 percent in the South Atlantic to 21 percent in the North Atlantic.

The private/rental boat mode accounted for the highest percentage of the catch in number for all subregions combined in 1986 with 62 percent. All subregions except for the South Atlantic (31 percent) had private/rental boat catches representing over 60 percent of the total catch.

The average weight of a fish, estimated from the Type A catch (those available for identification) for all subregions combined, was 0.67 kg (1.48 pounds) in 1986. The average weight of fish sampled ranged from 0.57 kg in the Mid-Atlantic subregion to 0.96 kg in the North Atlantic subregion.

Thirty-six percent of the 1986 catch by

[1]This article is taken from Current Fishery Statistics 8392 and 8393, prepared under the supervision of Mark C. Holliday. Past and present MRFSS personnel involved in the survey design, survey implementation, and analysis of data include David G. Deuel, Ronald J. Essig, Mark C. Holliday, W. Malon Scogin, and John F. Witzig.

Table 1.—Estimated total number of fish caught by Atlantic and Gulf coast marine recreational fishermen by species group and subregion, Jan.-Dec. 1986.

Species group	Catch in thousands[1]					Species group	Catch in thousands[1]				
	N. Atl.	Mid Atl.	S Atl.	Gulf	All reg.		N. Atl.	Mid Atl.	S Atl.	Gulf	All reg.
01. Sharks	33	1,141	452	695	2,322	41. Spotted seatrout	*	179	1,958	21,455	23,592
02. Sharks, dogfish	410	1,563	179	–	2,172	42. Weakfish	–	11,106	1,204	*	12,322
03. Skates/rays	521	409	306	404	1,639	43. Sand seatrout	*	*	*	6,404	6,404
04. Eels	42	285	–	54	410	44. Silver perch	*	–	154	298	465
05. Herrings	701	1,085	5,068	4,148	11,002	45. Spot	*	15,738	5,761	142	21,640
06. Freshwater catfishes	*	695	94	938	1,727	46. Kingfishes	*	656	3,271	4,102	8,029
07. Saltwater catfishes	*	–	3,033	15,331	18,368	47. Atlantic croaker	*	12,988	6,088	14,912	33,989
08. Toadfishes	–	2,705	559	200	3,464	48. Black drum	*	34	403	1,430	1,867
09. Atlantic cod	1,493	56	*	*	1,549	49. Red drum	*	57	553	3,513	4,123
10. Atlantic tomcod	349	–	*	*	355	50. Drums	*	38	237	1,281	1,554
11. Pollock	436	–	*	*	446	51. Mullets	*	46	1,713	4,582	6,341
12. Silver hake		160	*	*	168	52. Barracudas	*	–	253	221	477
13. Searobins	834	10,908	75	41	11,858	53. Tautog	4,179	4,996	–	*	9,186
14. Sculpins	318	–	*	*	323	54. Cunner	1,321	1,383	*	*	2,703
15. White perch	–	3,978	144	*	4,125	55. Little tunny/Atl. bonito	563	54	655	523	1,795
16. Striped bass	683	706	–	–	1,429	56. Atlantic mackerel	1,238	4,642	*	*	5,879
17. Black sea bass	981	30,257	1,677	1,824	34,739	57. King mackerel	*	–	592	147	753
18. Groupers	*	*	156	2,227	2,383	58. Spanish mackerel	*	–	1,066	7,914	8,987
19. Sea basses	*	–	138	1,152	1,300	59. Tunas/mackerels	33	534	150	209	927
20. Bluefish	10,646	18,379	3,101	541	32,667	60. Summer flounder	4,305	18,394	1,484	*	24,183
21. Jack crevalle	*	*	2,566	761	3,328	61. Gulf flounder	*	*	*	502	502
22. Blue runner	*	*	2,671	687	3,358	62. Southern flounder	*	–	441	2,568	3,021
23. Greater amberjack	*	37	123	282	442	63. Winter flounder	5,411	5,016	*	*	10,428
24. Florida pompano	*	–	1,830	253	2,099	64. Flounders	55	828	*	1,539	2,422
25. Jacks	*	148	747	1,815	2,710	65. Triggerfishes/filefishes	–	60	158	231	452
26. Dolphins	*	37	603	614	1,254	66. Puffers	–	391	378	227	1,000
27. Gray snapper	*	*	529	1,561	2,090	67. Other fishes	505	2,930	2,100	10,663	16,199
28. Red snapper	*	*	210	645	855						
29. Lane snapper	*	*	45	174	218	Totals	56,654	163,670	59,047	131,865	411,235
30. Vermilion snapper	*	*	56	303	359						
31. Yellowtail snapper	*	*	278	302	580						
32. Snappers	*	*	134	199	334						
33. Pigfish	*	104	338	1,011	1,453						
34. White Grunt	*	*	698	992	1,690						
35. Grunts	*	–	1,036	2,279	3,320						
36. Scup	21,567	10,794	*	*	32,361						
37. Pinfish	*	–	2,547	7,325	9,882						
38. Sheepshead	*	31	839	1,852	2,722						
39. Red porgy	*	*	–	255	269						
40. Porgies	*	–	134	88	225						

[1]An asterisk (*) denotes none reported; a dash denotes less than thirty thousand reported, though the figure is included in row and column totals.

weight, estimated from the Type A catch, for all subregions combined was from the EEZ. The percentage catch by weight in the EEZ was highest in the South Atlantic (45 percent), followed by the Middle Atlantic (41 percent), the North Atlantic (31 percent), and the Gulf (26 percent).

About 7.7 million anglers made 45.9 million fishing trips within their home state during 1986. Out-of-state anglers contributed an additional 15.7 million trips. The majority of all fishing trips within a state were made by coastal county residents of the same state. However, out-of-state anglers made more fishing trips than resident fishermen in Delaware. Residents of all 50 states were intercepted on either the Atlantic or Gulf coast in 1986.

The Middle Atlantic subregion accounted for the greatest number of fishing trips and participation by residents in 1986 with one-third of the Atlantic and Gulf coast total. This differs from 1985 when the Gulf subregion had the highest average number of trips and participants. However, the exclusion of Texas and South Atlantic and Gulf party-boat trips in 1986 may account for the differences between 1986 and previous years. The North Atlantic subregion had the fewest trips and participants for all 8 years of the survey. The private/rental boat mode accounted for the highest percentage of the fishing effort in 1986 in the North Atlantic and Middle Atlantic subregions. Most of the 1986 fishing effort in the South Atlantic and Gulf was in the shore mode.

Angler success, as measured by the average number of fish caught, was highest for the private/rental boat mode in the North Atlantic and Gulf subregions in 1986. Catch per trip was highest from the party/charter boat mode in the Middle Atlantic and from the shore mode in the South Atlantic. Overall, more than 70 percent of the anglers fishing in party/charter and private/rental boat modes were successful in catching one or more fish; about 50 percent of those fishing

the shore mode were successful in catching fish. The success rates for the private/rental boat mode in the Gulf subregion was the highest of all reported in 1986.

The coefficient of variation for the total number of fish caught in 1986 was 3 percent. At the 95 percent confidence level the actual total catch was between 389.9 and 432.6 million fish. Ninety percent of the species groups had coefficients of variation less than 30 percent. The lowest species group coefficients of variation were 7 percent for bluefish and spotted seatrout, and 8 percent for spot, red drum, and summer flounder.

Length-frequency histograms for selected species in 1986 were similar to 1983-85. A bimodal distribution was observed for bluefish, with a major peak at 450 mm and a secondary peak at 750 mm. This bimodal distribution is most likely the result of differences in the size of fish caught among fishing modes and areas. The length-frequency data for each species are highly aggregated in these plots so differences among subregions, modes, areas, and waves are masked. The regional nature of the recreational fishery is characterized by the varying composition of the catches. Therefore, the following discussion will focus on the significant changes in the catches of specific groups in the individual subregions.

North Atlantic

Scup and bluefish dominated the marine recreational fishery in the North Atlantic during 1986, as they did in 1979-85. These two species accounted for over 57 percent of the total catch in numbers in the subregion. Other frequently caught species in 1986 were summer flounder, tautog, Atlantic cod, cunner, and Atlantic mackerel. Catches of winter flounder, the top-ranked species in 1979-82 and 1985, were the lowest in the 8 years of the survey.

The private/rental boat catch from inland waters accounted for the largest proportion of the total number of fish caught in 1986 (36 percent). The private/rental boat mode alone accounted for 73 percent of the total number of fish caught. This was higher than the 1979-85 average private/rental boat mode contribution of 61 percent. In 1986 the inland area accounted for the greatest proportion of the catch in number with 44 percent. This was similar to 1979-82 and 1985, when the inland area accounted for the greatest proportion of the catch.

About 1.3 million New England residents participated in marine recreational fishing in the North Atlantic and made an estimated 5.8 million fishing trips in 1986. These effort statistics were similar to the 1979-85 means of 1.3 million participants and 5.7 million trips. Fishing activity was greatest during the July/August wave in 1986; about 8 percent of the coastal county residents of the North Atlantic States participated in marine recreational fishing during these months. Out-of-state residents made an additional 2.5 million fishing trips in this subregion.

Average catch rates for the boat fishing modes in 1986 were higher than 1979-85 mean values, while the shore mode in 1986 was lower than 1979-85 mean values for the combined man-made and beach/bank modes. The private/rental boat mode had the highest average catch rate with 8.1 fish/trip and the shore mode had the lowest catch rate with 2.3 fish/trip.

As in all previous survey years except 1980, bluefish was the most sought species in 1986. In 1986, winter flounder was ranked second, and Atlantic cod was ranked third. Since intercept interviews are conducted at the completion of a fishing trip, there may be some response bias introduced that correlates the species sought with what was actually caught.

The coefficient of variation for the total catch in number of fish was 7 percent in 1986. Based on the standard error of the estimate, the actual total catch in number of fish was between 49.0 and 64.3 million fish in 1986 at the 95 percent confidence level. Although the precision of the catch estimates for individual species groups varied greatly, 65 percent of the species groups had coefficients of variation less than 30 percent. The lowest coefficients of variation were 13 percent for scup and 16 percent for bluefish.

Middle Atlantic

Black sea bass, summer flounder, bluefish, and spot composed 50 percent of the total catch in number in the Middle Atlantic in 1986. These same species were major components of the 1979-85 catches. The catch of black sea bass was considerably higher in 1986 than in 1979-85, while the estimated catch of winter flounder was significantly lower in 1986.

The private/rental boat catch from inland waters accounted for the greatest percentage of the total number of fish caught in the subregion in 1986 with 38 percent. The private/rental boat mode alone accounted for about 63 percent of the total number of fish caught. The 1979-85 average percentage of catch from the private/rental boat mode was 57 percent. Seventy-four percent of the marine recreational catch in number in 1986 was from inland waters or within 3 miles of shore.

About 2.5 million residents of the Middle Atlantic States participated in marine recreational fishing during 1986. Coastal residents made about 72 percent of the marine fishing trips. Residents of the subregion made an estimated 15.3 million marine fishing trips in 1986; an additional 5.2 million trips were made by out-of-state residents. Fishing activity was greatest in the July/August wave with about 8 percent of the sampled residents of the coastal counties participating in the fishery. Catch rates in all fishing modes in 1986 were higher than the 1979-85 average catch rates. The average catch rate was highest for party/charter boat mode with 13.6 fish/trip.

As in previous years summer flounder and bluefish were the most sought individual species in 1986 with about 31 percent of the respondents indicating a preference for one of the species. No other species accounted for more than 10 percent of the responses during 1986.

The coefficient of variation for total number of fish caught in 1986 was 5 percent. At the 95 percent confidence level the actual total catch was between 147.0 and 180.4 million fish. Species groups with coefficients of variation less than 10 percent were bluefish (7 percent), summer flounder (8 percent), and spot (9 percent).

South Atlantic

No species group clearly dominated the recreational fishery in the South Atlantic during 1986. Atlantic croaker, spot, and herrings were the most abun-

dant species caught in 1986 and accounted for about 29 percent of the total catch.

Anglers fishing in the shore mode took about 67 percent of the recreational catch in 1986. Seven percent of the total number of fish was taken in the ocean greater than 3 miles from shore area. Part of the percent change in catches among the modes is attributable to the exclusion of the party boat catch from the 1986 survey. Average catch rates in 1986 were similar to those in 1979-85. Catch rates were highest in the shore mode with an average of 4.3 fish/trip and lowest in the charter boat mode with an average of 3.2 fish/trip.

An estimated 1.7 million residents of the South Atlantic States participated in the marine recreational fishery in 1986. The estimated participation was lower than the 1979-85 average of 2.1 million South Atlantic resident fisherman and may be attributed to exclusion of party boats from the sample frame. Coastal residents made about 77 percent of the estimated 14.8 million trips in 1986. Fishing activity was greatest in the September/October wave with about 11 percent of the coastal population of the subregion participating in the fishery. Over 7 percent of all households surveyed reported marine recreational fishing activity during each wave.

As in 1983-85, four of the five most highly sought species were spotted seatrout, bluefish, red drum, and king mackerel. Dolphins were added to the most-sought list in 1986. The coefficient of variation for the total number of fish caught during 1986 was 5 percent. The actual total catch was 53.0 to 65.1 million fish at the 95 percent confidence level.

Gulf of Mexico

Forty-one percent of the total marine recreational catch in the Gulf of Mexico in 1986 consisted of various members of the Sciaenid family (i.e., drums, seatrouts, croakers) an increase from 34 percent of the total catch in 1985. Spotted seatrout was the most commonly caught species with 16 percent of the total catch. Other commonly caught species groups were saltwater catfishes, Atlantic croaker, Spanish mackerel, sand seatrout, and pinfish. The exclusion of Texas and party boat sampling in the Gulf subregion in 1986 may account for several apparent changes in Gulf of Mexico results. In the 1985 MRFSS, Texas accounted for 24.8 million fish caught on 7.3 million trips by 1.8 million participants. The exclusion of party boats, many of which target reef fish, may contribute to the changes in species sought for the subregion.

The private/rental boat-ocean 3 mile or less mode-area combination accounted for the largest proportion (40 percent) of the catch in 1986. About 71 percent of the total number of fish was taken by anglers in the private/rental boat mode. Fourteen percent of the total number of fish was taken in the ocean greater than 3 miles from shore. Average catch rates increased in 1986 from the 1985 rates for all modes. The private/rental boat mode had the highest catch rate (14.5 fish/trip). The shore mode had the lowest catch rate (4.0 fish/trip).

An estimated 2.2 million residents of the Gulf states participated in marine recreational fishing during 1986. Over 8 percent of the households contacted in the telephone survey reported marine fishing activity in all waves of 1986. Spotted seatrout and red drum were the most highly sought species in 1986 as in 1983-85.

These two species represented 34 percent of the responses to species sought. As in the South Atlantic, the diversity of species sought was much higher than the North Atlantic and Middle Atlantic subregions. The coefficient of variation for the total number of fish caught was 3 percent in 1986. The actual total catch in number of fish was between 122.8 and 140.9 million fish at 95 percent confidence level.

Overall Pacific Coast Results

Combined MRFSS and state survey estimates of total Pacific landings were approximately 32 million fish in 1986. This estimate includes the salmon catch for the Pacific coast. These combined estimates were about 5 percent greater than the MRFSS estimates in 1986. The total Pacific coast catch of salmon was about 1.2 million fish in 1986, a 23 percent increase from 1985 and a 50 percent increase from 1984. The salmon catch in 1986 was about 27 percent lower than the 1983 catch.

The effect of adding state survey data to MRFSS estimates varied by state. In California where salmon catches were the lowest of the three Pacific coast states, there was little impact on the total number of fish caught. Estimated numbers of fish caught in Oregon increased significantly (32 percent) with the addition of state data. Most of the increase in Oregon was attributable to the salmon catch and the by-catch of black rockfish in the salmon fishery. Salmon catches increased the estimate in Washington by 15 percent in 1986.

For 1986, the MRFSS estimated that 55 million fish were caught by marine anglers on the Pacific coast (Table 2), compared with 43 million fish in 1985 and 47 million in 1984. As in the previous 5 years the most commonly caught species in 1986 was Pacific mackerel. The contribution of the rockfishes to the total catch in numbers dropped from 26 percent in 1985 to 18 percent in 1986. The rockfishes, however, remained the most frequently caught family by number in 1986.

About 44 percent of the total Pacific catch by number was released alive in 1986, an increase of 5 percent from 1985. Fifty-six percent of the fish caught in Southern California were released alive compared with 29 percent in Northern California, 34 percent in Oregon, and 14 percent in Washington. As in previous years, the ocean within 3 miles of shore accounted for the majority of the Pacific catch by number (56 percent). Historically, catch in number by fishing mode has fluctuated considerably among years. However, 1986 was very similar to 1985.

The party/charter and private/rental boat modes accounted for 73 percent of the total catch in 1986, compared with 75 percent in 1985. The share of the total catch attributable to the private/rental boat mode (43 percent) and the party/charter boat mode (30 percent) did not change significantly from 1985. Catch from the shore mode made up the remainder of the catch.

During 1986, the smelt, sea bass, surfperch, and the sculpin families each accounted for 10 percent or more of the

Table 2.—Estimated total number of fish caught by west coast marine recreational fishermen by species group and subregion, Jan.-Dec. 1986.

Species group	Catch in thousands[1] S. California	N. California	Oreg.	Wash.	All regions	Species group	Catch in thousands[1] S. California	N. California	Oreg.	Wash.	All regions
01. Spiny dogfish	104	–	*	461	577	41. Brown rockfish	158	216	*	–	392
02. Sharks, other	145	758	*	*	903	42. Copper rockfish	165	76	–	95	337
03. Sturgeons	*	74	–	–	92	43. Widow rockfish	122	42	–	–	165
04. Pacific herring	–	277	–	171	482	44. Yellowtail rockfish	218	296	–	–	534
05. Northern anchovy	*	37	–	–	40	45. Chilipepper rockfish	189	363	*	*	552
06. Surf smelt	*	1,556	120	3,669	5,345	46. Quillback rockfish	*	–	–	83	95
07. Smelts, other	*	–	–	567	578	47. Black rockfish	36	465	319	81	902
08. Pacific cod	*	*	*	136	136	48. Blue rockfish	559	327	50	–	945
09. Pacific tomcod	*	–	–	55	68	49. Bocaccio	677	191	–	–	868
10. Walleye pollock	*	*	*	158	158	50. Canary rockfish	125	276	–	–	426
11. Pacific hake	–	61	*	–	104	51. Greenspotted rockfish	225	102	*	*	327
12. Silversides	236	–	–	*	239	52. Olive rockfish	197	66	*	*	263
13. Jacksmelt	207	146	–	*	356	53. Gopher rockfish	439	71	*	*	511
14. Striped bass	*	75	*	*	75	54. California scorpionfish	307	*	*	*	307
15. Kelp bass	4,500	–	*	*	4,502	55. Rockfishes, other	2,387	933	35	210	3,566
16. Spotted sand bass	604	*	*	*	604	56. Sablefish	–	37	–	–	52
17. Barred sand bass	2,270	*	*	*	2,270	57. Kelp greenling	–	137	89	45	281
18. Sea basses, other	1,141	*	*	*	1,141	58. Lingcod	169	264	46	58	536
19. Yellowtail	–	*	*	*	–	59. Greenlings, other	*	78	–	–	117
20. White croaker	2,117	738	*	*	2,855	60. Cabezon	113	93	–	–	231
21. California corbina	60	*	*	*	60	61. Sculpins, other	81	1,127	387	370	1,964
22. Queenfish	551	*	*	*	551	62. Sanddabs	269	236	*	100	605
23. Croakers, other	312	–	*	*	312	63. California halibut	1,339	–	*	*	1,349
24. Opaleye	113	*	*	*	113	64. Rock sole	–	–	*	52	62
25. Halfmoon	291	*	*	*	291	65. Starry flounder	–	32	–	–	59
26. Shiner perch	74	206	46	62	388	66. Flatfishes, other	53	57	–	140	251
27. Striped seaperch	–	117	44	30	200	67. Other fish	1,180	433	155	112	1,880
28. Black perch	–	41	*	*	67						
29. Walleye surfperch	171	55	32	–	261	Totals	35,334	11,227	1,754	6,998	55,312
30. Silver surfperch	101	34	–	–	150						
31. White seaperch	–	86	–	*	94						
32. Pile perch	–	286	80	48	432						
33. Redtail surfperch	*	61	110	53	224						
34. Barred surfperch	538	178	*	*	716						
35. Surfperches, other	207	383	72	110	771						
36. Pacific barracuda	1,160	*	*	*	1,160						
37. California sheephead	204	*	*	*	204						
38. Pacific bonito	3,970	–	*	*	3,970						
39. Chub mackerel	7,086	79	*	*	7,165						
40. Tunas	57	–	*	*	67						

[1]An asterisk (*) denotes none reported. A dash denotes less than 30,000 reported. However, the figure is included in row and column totals.

total number of fish caught in the inland area. The rockfish family accounted for less than 4 percent of the total catch in numbers during 1986 in the inland area.

The rockfishes made up about 19 percent of the total number of fish caught in the ocean within 3 miles of shore during 1986 compared with 25 percent in 1985. As in 1985, Pacific mackerel was the most abundant species caught during the year in this area. The sea basses, tunas, and mackerels group, and the sciaenids each constituted more than 10 percent of the total catch in the inshore ocean area during 1986.

During 1986, about 35 percent of the total number of fish caught in the ocean >3 miles from shore consisted of various species of the rockfish family, a decrease from 48 percent in 1985. The tunas and mackerels accounted for about 32 percent of the total recreational catch in the offshore area during 1986 with Pacific mackerel accounting for 22 percent of the total catch.

Surf smelt dominated the shore catch with 36 percent of the total catch within the mode in 1986. No other species accounted for more than 5 percent of the catch within the mode. Pacific mackerel was the most abundant species caught in the party/charter and private/rental boat modes. Pacific bonito, white croaker, barred sand bass, and kelp bass each accounted for more than 5 percent of the total catch in the boat modes.

It was not possible to estimate the total number of distinct participants in the Pacific coast marine recreational fishery in 1986 with the MRFSS method because an individual can fish in more than one state. A Californian fishing in Oregon would be double-counted if included as a California resident participant and an out-of-state participant in Oregon. Estimates were made on a subregion basis only. In 1986 southern California had the most fishermen, followed by northern California, Washington, and Oregon.

About 11.0 million trips were taken by Pacific coast fishermen in 1986, an increase from 9.9 million trips in 1985 and 10.1 million trips in 1984. Over 88 percent of these trips were taken by coastal

residents, while noncoastal residents took about 4 percent and out-of-state residents took 7 percent of the trips. Forty-five percent of all fishing trips on the Pacific coast in 1986 were in the private/rental boat mode, 15 percent in the party/charter boat mode, and 40 percent in the shore mode.

The coefficient of variation for the catch estimate of all species combined on the Pacific coast was 3 percent in 1986. This coefficient was similar to the coefficients of variation of 2-4 percent reported for 1980 through 1985. Based on the standard error the total catch in 1986 in numbers of fish was between 52.2 million and 58.5 million fish at the 95 percent confidence limit. Length frequency histograms for selected species in 1986 were virtually identical to those for previous years. Since the length frequency data for each species are highly aggregate in these plots, differences among subregions, modes, areas, and waves are masked.

Southern California

Pacific mackerel accounted for 20 percent of the total catch in numbers in this subregion during 1986. Other species accounting for more than 10 percent of the total catch were kelp bass (13 percent) and Pacific bonito (11 percent). As in the previous 6 years, Pacific mackerel was the most commonly caught species. Barred sand bass and white croaker each accounted for more than 5 percent of the total catch in numbers in 1986.

The rockfish complex accounted for 27 percent of the weight of the catch available for identification in 1986 compared to 34 percent in 1985. Pacific mackerel, barred sand bass, kelp bass and Pacific bonito accounted for 36 percent of the total weight of the identified catch. Overall, about 56 percent of the total catch in number was released alive. The proportion of the fish released alive varied considerably among species groups with over 90 percent of all California halibut caught being released alive to less than 10 percent of the catch of some species of rockfish being released.

About 88 percent of the total catch in number in 1986 was taken from boat modes, about the same proportion as in 1983-85. In 1986 the private/rental and party/charter modes accounted for 48 percent and 40 percent, respectively, of total catch in number for the subregion. In 1986, the May/June wave provided the highest percentage of the catch by number. July/August had the highest proportion of the total catch in the previous 3 years. About 21 percent of the total catch in number were caught during this period.

An estimated 1.4 million southern California residents participated in marine recreational fishing in the subregion in 1986 compared to 994,000 in 1985 and 1.2 million in 1983-1984. Northern California residents fishing in southern California were considered out-of-state residents for the purpose of estimating participation. Therefore, it is not possible to estimate total participants for California because of potential double-counting.

As in the previous 6 years of the survey, almost 90 percent of the trips in this subregion in 1986 were taken by southern California coastal county residents. About 6.1 million trips were made in the subregion in 1986, an increase from the 1985 estimate of 5.3 million trips. Fishing trips in southern California accounted for the largest proportion of the total number of trips taken on the Pacific coast (55 percent).

Anglers targeted a wide variety of species in 1986 with only California halibut being targeted by more than 5 percent of the anglers interviewed. Since the intercept interviews were conducted at the completion of a fishing trip, there is probably some response bias introduced that correlates the species sought response with what was actually caught. In addition, a prestige bias may also be present if respondents gain satisfaction by responding they were seeking highly desirable species.

As in 1983-85, the party/charter mode had the highest catch rates in 1986, with an average of 9.7 fish per trip. The private/rental mode averaged 6.5 fish per trip in 1986, compared with the 1983-85 average of 5.3 fish per trip. Catch rates for the shore mode averaged 1.9 fish per trip. Over 95 percent of fishermen intercepted in 1986 in the southern California subregion were residents of California. Residents of 43 of the 50 United States were intercepted in southern California.

The coefficient of variation for the total number of fish caught was 3 percent in 1986. This value was similar to the coefficients of variation of 2 to 3 percent reported in 1980 through 1985. The actual total catch in number of fish in 1985 was between 33.4 and 37.2 million fish at the 95 percent confidence level. This estimate is significantly higher than the 1985 estimate of 27.6 million fish. The precision of the catch estimate varied among species groups. Coefficients of variation ranged from 7 percent for barred sand bass to 34 percent for widow rockfish.

Northern California

As in the previous 3 years, surf smelt was the leading species in number of fish caught in northern California in 1986 accounting for 14 percent of the total catch in number. The only other individual species to account for more than 5 percent of the total catch was white croaker. The rockfishes composed 30 percent of the total number of fish caught in the subregion in 1986 compared to 36 percent in 1985. Lingcod was the top ranked single species by weight of catch (available for identification) in 1986 (15 percent). The rockfish family accounted for approximately 44 percent by weight of the catch during 1986.

The proportion of the total catch in the subregion attributable to a particular mode and area has fluctuated considerably over the 8 years of the survey. The private/rental-ocean 3 miles or less from shore combination accounted for the most fish in 1986 (25 percent). Twenty percent of the total catch in number was taken in the shore-ocean <3 miles combination. The boat modes accounted for about 60 percent of the total catch in the subregion in 1986, about the same proportion as in 1985. The shore mode accounted for 40 percent of the total number of fish caught in 1986. As in previous years, catch by number was highest in the summer. Peak catch by number was in the July/August wave with about 32 percent of the total catch being taken in this 2-month period.

An estimated 632,000 northern California residents went saltwater fishing in the subregion in 1986 compared with

725,000 in 1985. The 1986 estimate is comparable to the estimated participation for the subregion for 1980 through 1984. About 90 percent of the total number of anglers in the subregion were northern California residents. Four percent of all households contacted in the telephone portion of the survey indicated some saltwater fishing activity during the year. About 2.8 million fishing trips were taken in the subregion in 1986, a slight increase from the 2.5 million trips taken in 1985. Overall, trips in northern California composed 25 percent of the Pacific coast total. No single species was targeted by more than 10 percent of the anglers intercepted in the survey. The rockfish and surfperch families were targeted by more than 10 percent of the anglers interviewed.

The party/charter boat mode had the highest catch rates per trip (with an average of 8.6 fish per trip). Catch rates in the other two modes were less than half the catch rate in party/charter boat mode. Eighty-seven percent of the intercepted fishermen in the northern California subregion were residents of northern California. Less than 3 percent of the fishermen intercepted in the subregion were not residents of California. Highly avid fishermen are over-represented in the totals because the probability of being interviewed in the intercept survey is directly proportional to the number of trips taken by an individual.

The estimated total catch for the northern California subregion was 10.1-12.4 million fish in 1986 at the 95 percent confidence level. The 1986 estimate is not significantly different from the 1985 estimate of 10.5 million fish. The coefficient of variation for the total number of fish caught in the northern California subregion was 5 percent. This error rate is comparable to the error rates reported for 1981 through 1985. Coefficients of variation ranged from 10 percent for "other rockfishes" to 64 percent for white seaperch.

Oregon

An estimated 1.8 million fish were caught in Oregon during 1986 compared with 1.9 million fish in 1985. This catch represented 3 percent of the total west coast catch. The estimated total recreational catch in numbers had decreased annually from 3.2 million fish in 1981 to 1.2 million fish in 1984. The 1986 and 1985 fishing years may mark the reversal of this downward trend in catch. As in previous years no single species dominated the catch during 1986. However, black rockfish accounted for 18 percent of the total catch during the year and surf smelt, redtail surfperch, kelp greenling, and other sculpins each accounted for more than 5 percent of the total 1986 catch. Black rockfish accounted for the largest proportion of the estimated total weight of the catch (available for identification) in Oregon during 1986 (26 percent). This species was also dominant by weight during the previous 5 years.

Shore-based anglers accounted for the largest proportion of the catch in the state in 1986 (57 percent). The inland area accounted for 61 percent of total catch in numbers during the year. The ocean area <3 miles from shore accounted for 37 percent of the total catch and the offshore area (>3 miles from shore) accounted for about 1 percent of the total catch in the subregion.

Catch in number has varied seasonally among years. In 1986 the summer waves accounted for the greatest proportion of the total catch with 27 percent of the catch being taken in May/June and 24 percent in July/August. Peak catches by weight occurred during September/October. About 277,000 Oregon residents fished in the State during 1986 compared with 210,000 Oregon participants in 1985. Estimated participation by Oregon residents in 1986 was comparable to participation in the previous 2 years, however participation by state residents was considerably less than estimates for 1980 through 1983. Oregon residents comprised 91 percent of the anglers in the State in 1986.

About 960,000 fishing trips were taken in Oregon in 1986 compared with an estimated 765,000 fishing trips made during 1985 and 595,000 trips in 1984. The 1986 estimate is comparable to the peak activity years of 1981-83 which averaged 970,000 trips. Over 86 percent of the respondents to the species sought questions in Oregon in 1986 indicated either "other fish", or "surfperches, other." No single species accounted for more than 5 percent of the responses.

As in 1983-85, the party/charter boat mode accounted for the highest catch rate per trip in 1986 with an average of 3.4 fish per trip. Shore anglers caught 2.6 fish per trip and anglers in the private/rental boat mode averaged 1.3 fish per trip. The estimated total catch for Oregon was 1.6 to 1.9 million fish in 1986 at the 95 percent confidence level. The 1986 estimate is comparable to the estimated catch for the state in 1985. The coefficient of variation for the total number of fish caught in Oregon was 4 percent in 1986. The coefficients of variation ranged from 10 percent for kelp greenling to 34 percent for blue rockfish.

Washington

Total Washington catch in number was estimated at 7.0 million fish in 1986, more than double the estimated 1985 catch of 3.1 million fish. Surf smelt accounted for 52 percent of the total catch in 1986. No single species accounted for more than 5 percent of the remaining catch. As in Oregon the estimated total catch in Washington had been declining since 1981 when an estimated 9.0 million fish were caught; 1986 may be a turning point in the recreational catch in the state.

Black rockfish, lingcod, and walleye pollock combined accounted for 31 percent of the catch by weight in 1986 compared with 40 percent in 1985, 35 percent in 1984, and 50 percent in 1983 for these same species. About 77 percent of the Washington catch by number was made in the inland area in 1986. Shore based anglers accounted for the greatest proportion of the total catch in 1986 (75 percent). The private/rental boat mode contributed 22 percent of the catch in 1986 compared with 59 percent in 1985 and 48 percent in 1984. The large surf smelt catch in 1986 was taken entirely in the shore mode, and thus these proportions are skewed towards the shore mode. As in the previous 3 years, the July/August wave accounted for the greatest catch by number in 1986 (38 percent). Catch by weight also peaked in July/August.

An estimated 280,000 residents of Washington made 1.1 million fishing

trips in 1986. These figures are not significantly different from the 1985 estimates of 286,000 resident participants and 1.3 million fishing trips. Out-of-state residents made an additional 67,000 trips in 1986. The majority of all marine fishing trips taken in Washington were made in the private/rental boat mode (61 percent). Over 76 percent of the fishermen interviewed in Washington responded that they sought "other fish" or "none." No single species accounted for more than 5 percent of the responses in 1986. However, this excludes responses from salmon fishermen who were not sampled by the MRFSS.

The estimated total catch for the state was 4.8-9.2 million fish at the 95 percent confidence level. The 1986 estimated catch was significantly higher than the 1985 catch. The coefficient of variation for total number of fish caught was 16 percent in 1986, the highest for any of the Pacific coast subregions. Overall, the Washington coefficient of variation was heavily affected by the variability of the smelt fishery catch. The coefficients of variation ranged from 69 percent for "smelts, other" to 9 percent for spiny dogfish. (Sources: CFS 8392 and 8393.)

New Jersey-D.C. Striped Bass Plans Approved

The Interior and Commerce Departments jointly approved plans by New Jersey and the District of Columbia for managing striped bass, *Morone saxatilis*, in their jurisdictions earlier this year, averting a threatened 1 April 1987 Federal moratorium on striped bass fishing, report agencies for the two departments.

New Jersey and the District of Columbia were informed in February that pending regulations aimed at managing their striped bass populations were not in compliance with the Atlantic States Marine Fisheries Commission's Interstate Fisheries Management Plan. That plan called for the Atlantic states and the District of Columbia to take steps to protect the striped bass spawning stock in an effort to speed recovery of the highly prized fish.

On 24 March, New Jersey amended legislation on striped bass fishing to set a 31-inch minimum size limit until 31 July 1987, increasing to 33 inches until 30 September 1988. Only recreational fishing will be permitted in the state, and fishermen will be allowed to possess no more than five fish at a time.

The District's regulations, which went into effect 27 March, imposed a 24-inch minimum size limit and held fishermen to a two-fish bag limit. The striped bass season will be closed from 1 December to 31 May. Fishing in the District will be limited to recreational fishermen.

In separate letters sent to New Jersey's Governor Thomas H. Kean and to Washington's Mayor Marion Barry, William E. Evans, head of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, and Frank Dunkle, director of Interior's Fish and Wildlife Service, praised the jurisdictions' responsiveness in adopting striped bass regulations and commended their work "to contribute to cooperative management efforts on striped bass."

Collect Rewards for Albacore Tags Returned

Albacore, *Thunnus alalunga*, tagged with NMFS yellow and red tags are worth cash when properly returned. For each returned yellow tag the NMFS will pay $2.00 and give a baseball cap with a special albacore tagging logo. There is no need to return those fish; just forward the yellow tag to the NMFS address on it.

For red tags, however, the NMFS will purchase the fish at the cannery price and pay a reward of $50.00 for each fish returned with red tag intact. Notify the NMFS, P.O. Box 271, La Jolla, Calif., at telephone (619) 453-2820.

To collect the reward for yellow or red tags you must record where, when, and how the fish was caught, plug the length of the fish (tip of lower jaw to fork of tail). In addition, the American Fishermen's Research Foundation will award cash prizes for yellow and red tag numbers drawn in an annual lottery.

Fishery Agencies Tag 150,000 Atlantic Salmon

In early 1987, the Federal Government tagged about 150,000 small Atlantic salmon with external, "Carlin"-type tags and released them into New England's Connecticut and Penobscot Rivers. About 100,000 tagged, juvenile (or "smolt") salmon were released during early May into Maine's Penobscot River. About 50,000 tagged smolts were released during early April into Massachusetts, Connecticut, and Vermont tributaries to the mainstem.

The Carlin tag is a $^5/_8$-inch long, green or blue-colored, oval-shaped disc that is attached behind the dorsal (top) fin of the 7-9 inch long smolt. Each of these tags has a number on one side and the phrase, "REWARD, NMFS, WOODS HOLE, MA, USA," on the other side.

Although the tags indicate a reward (which is $12), all states in the Connecticut River Basin have made it illegal to keep any Atlantic salmon that has been caught in the river or its tributaries. Maine has made it illegal to keep any Atlantic salmon (whether of sea-run or land-locked variety) less than 14 inches long that has been caught in the state's waters. Therefore, Atlantic salmon bearing these Federal tags are NOT exempt from any applicable state fishing regulations. Consequently, fishermen catching a tagged smolt Atlantic salmon were warmed that they should immediately return the fish to the water unharmed.

The various state regulations that prohibit the harvesting of Atlantic salmon

smolts protect the tagged smolts as they descend to the sea where they can grow, mature, and someday return as large, highly prized gamefish. These regulations also support the purpose of the tagging program to gather needed data on the at-sea habits of adult Atlantic salmon.

The tagging program, a joint effort among the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the New England states, attaches Carlin tags to about 150,000 of the million-plus, hatchery-produced smolts which are annually released into New England rivers as part of a long-term effort to restore the region's salmon populations and fisheries. Tag returns provide needed data on the Atlantic salmon's at-sea habits, including migration routes, migration timing, concentration areas, and fishing vulnerability. Such data permit the United States to: Enact better salmon management measures for its territorial waters, and negotiate better salmon management measures for other national and international waters through U.S. membership in the treaty-based North Atlantic Salmon Conservation Organization.

NASCO Further Protects Atlantic Salmon From Interception Fisheries

August 25, 1987 began a series of three dates which will be milestones in the Atlantic salmon conservation movement. On that date and on October 1 and 15, various controls take effect which will—for the first time—largely control salmon "interception" fisheries throughout the species' entire natural range.

Interception fisheries involve the harvesting by one country's fishermen of the salmon produced in another country's rivers, and principally occur in three locations: 1) Off the Faroe Islands (Danish Territory between Iceland and mainland Europe) where mostly European-origin but some North American-origin salmon are caught; 2) off Newfoundland and Labrador where mostly North American-origin salmon but some European-origin salmon are caught; and 3) off West Greenland where significant numbers of both North American- and European-origin salmon are caught.

These comprehensive controls on interception fisheries resulted from the fourth annual meeting of the treaty-based North Atlantic Salmon Conservation Organization (NASCO) held 7-11 June 1987 in Edinburgh, Scotland. At the June meeting, NASCO enacted its first conservation measures for the Faroese fishery and renewed its conservation measures for the Newfoundland-Labrador and West Greenland fisheries, which it first enacted at last year's annual meeting.

For the Faroese fishery, NASCO has agreed to cap the fishery, on a trial basis, at a combined harvest of 3,945,000 pounds for the 1987-88, 1988-89, and 1989-90 fishing seasons, with the harvest in any one season not to exceed 1,380,000 pounds. NASCO will also oversee effort restrictions in the Faroese fishery whose season opened 1 October and ends 31 May. These conservation measures are the first ones enacted by NASCO through its component North-East Atlantic Commission.

At last year's annual meeting, NASCO enacted conservation measures through its other two component Commissions, the North American and the West Greenland. The North American Commission, composed of the United States and Canada, agreed last year to close the commercial salmon fishery off Newfoundland and Labrador on 15 October, instead of the traditional 31 December, due to the high percentage of U.S.-origin salmon being harvested off those Canadian provinces in the fall. The 15 October closure was in effect again in 1987.

The West Greenland Commission, composed of the United States, Canada, Denmark (in respect to its Territory of Greenland), and the European Economic Community, agreed in 1986 to an annual total allowable catch in the West Greenland fishery of 1,875,000 pounds, based on a 1 August opening, which would be in effect for both the 1986 and 1987 fishing seasons. The agreement stipulates that if the opening is changed to a later date, the catch may be increased according to the projected increase in weight of the salmon between 1 August and the later opening. The Home Government of Greenland elected to open the 1987 West Greenland fishery on 25 August with an increased catch of 2,095,000 pounds.

Allen E. Peterson, Jr., one of the three U.S. Commissioners to NASCO and the Director of the National Marine Fisheries Service's Northeast Fisheries Center, lauded NASCO's actions. "The agreement reached by NASCO's North-East Atlantic Commission to regulate salmon harvests completes the cycle within NASCO. In just 4 short years, all three Commissions have taken definitive steps to reduce the harvests by one country's fishermen of the salmon produced in another country's rivers. This will now free the Commissions to address other important issues for which they have responsibility."

Atlantic Salmon Sampled in Canadian, Greenland Commercial Fisheries

U.S. scientists from Maine's Atlantic Sea-Run Salmon Commission and from the NMFS Northeast Fisheries Center were sent to Canada and Greenland during the summer of 1986 to collect data on the Atlantic salmon, *Salmo salar*, fisheries of Labrador and West Greenland. Since those fisheries intercept salmon of both North American and European origin, visiting scientists were granted permission not only to collect biological data, but also to recover tags from the commercial catch to determine the nation of origin of the individual fish in the catch.

For the study of stock composition and

the estimation of the harvest of U.S. salmon in those fisheries, smolts from U.S. hatcheries are now being marked with coded-wire tags prior to their seaward migration. The tags are subsequently detected in adult salmon with a magnetic sensor, then removed from the fish for interpretation. The tags, <1 mm long, contain information on the nation, river, and hatchery of origin. Tags are recaptured beginning 1 year after smolt release; thus the sampling efforts in summer 1986 were able to recover tags implanted in the 1985 smolt class. Sampling this year, summer 1987, will be to recover tags from the 1986 smolt class and the 1985 tags still at large.

Hawaii's Recreational Fishery Worth $200 Million

Money may not buy happiness, but happiness gained through recreational boat fishing is worth a hefty $199 million, according to a recently completed study on noncommercial fishing in Hawaii. That dollar figure excludes the $24 million the anglers spend annually on fishing gear, bait, ice, food, and transportation.

Discussions were held with boat clubs on Oahu, the Big Island, Maui, and Kauai to assess the economic value of Hawaii's recreational fishing, which the study defines as any fishing that is not full-time commercial. Included in the study's assessment are nonmarket goods, such as the joy of fishing. Although nonmarket goods have no monetary value, they can be degraded or enhanced by public and private decisions concerning Hawaii's marine fisheries. Estimating the economic dollar value of nonmarket goods is important in comparing the costs and benefits of fisheries management, development, and enhancement projects. The study was sponsored by the NMFS Southwest Fisheries Center's Honolulu Laboratory.

"This is the first time that the total economic value of recreational fishing has been estimated for Hawaii. The figures show how important the noncommercial fishery is to the people of Hawaii," said Richard S. Shomura, Director of the Honolulu Laboratory. Fishery landings by 6,700 noncommercial fishermen in Hawaii are an estimated 21 million pounds; $22 million is generated annually by the sale of half these fish. By comparison, commercial fish landings were 19.4 million pounds, worth $32 million in 1986, as estimated by the Honolulu Laboratory.

Annually, the average noncommercial fisherman takes 30 fishing trips and catches 1,500 pounds of fish, of which almost half is sold. The rest is kept for personal use, given to friends and family, or used as bait or other purposes. The study revealed that people fish for a variety of reasons, including excitement, relaxation, the chance to be with friends and family, getting fresh fish to eat, and earning extra money.

This study used an experimental technique that combines "contingent valuation" with information developed through "focus groups" of fishing clubs throughout Hawaii. Used increasingly by economists to reveal nonmarket values and estimate the direct expenditures of participants, this technique is still controversial, and the estimates are subject to reevaluation.

Results from a full recreational valuation survey in Hawaii could be useful to planners in making decisions about trade offs between commercial and recreational fishing interests, or between fishing interests and other users of our ocean environment. As an example, the Western Pacific Regional Fishery Management Council's (WPRFMC) interest in reducing foreign tuna fishing in Hawaii's 200-mile extended economic zone might be enhanced by this study's finding that as much as 40 percent of the noncommercial landings in Hawaii are tuna.

The Honolulu Laboratory is now involved in a project to design an ongoing survey of recreational fishing in Hawaii. Funded cooperatively with the WPRFMC, this new project attempts to develop consistent estimates of recreational fish landings as a basis for improving fisheries management in Hawaii. Results of the design study are expected by the year's end, and a State of Hawaii survey based on these results is expected to begin at that time.

Marine Angling in Australia

Recreational fishing is extremely important and valuable to Australian society and to that nation's economy, according to recent reports[1]. Indeed, data compiled for the Australian Recreational and Sport Fishing Confederation indicate that there are about 5 million Australians who go fishing for sport and recreation each year. Thus, recreational and sport fishing is a huge industry there; in fact, it is one of the biggest industries in the country and is one of the biggest outdoor participation sports. Recreational and sport fishing is worth in excess of $2.2 billion to the Australian economy each year, the Confederation reports.

The Australian Recreational and Sport Fishing Confederation is a national body representing and working for Australia's 4.5 million recreational and sport fishermen. It is not a fishing club and does not have individual members. Rather, its membership comprises all seven national sport fishing interest groups: Australian Anglers' Association, Australian Casting Association, Australian Fresh Water Fisherman's Assembly, Australian National Sport-fishing Association, Australian Underwater Federation, Game Fishing Association of Australia, and Native Fish Australia.

Angling Popularity

Fishing reportedly ranks third among the most popular outdoor recreational activities in Australia. Ranked ahead of it are, first, swimming (not in a pool) and playing court games like tennis, squash, etc. Ranked below it, in order, are swimming in public pools, physical fitness activities, and camping and caravaning. About 3 percent of Australian adults participate in skin/scuba diving.

Saltwater Fishing

According to Australia's first "National Survey on Recreational Fishing," about 67 percent of the nation's anglers are male, while 50 percent of the males between the ages of 18 and 44 participate in recreational fishing. Most anglers (92 percent) prefer to fish with bait, while those using spinning lures number 26 percent; 18 percent utilize pots and/or rings to take crabs and/or prawns. Most Australian angling is also done in saltwater (including estuaries), primarily from the beach or from rocks (32 percent), while 26 percent fish from boats in bays or estuaries, and 21 percent fish from jetties and wharves.

Slightly over half (56 percent) of all Australian households own some type of fishing tackle, researchers report, and the average value of the particular angling tackle and related clothing articles (i.e., rubberized or waterproof clothing, angling jackets or vests, etc.) is nearly $400. About one-third of all households reported either owning or having access to boats which are mainly used for fishing. It was also reported that in the 12-month period prior to the national survey (made in July 1984), Australian anglers spent $170 million on tackle and related clothing articles and $495 million on boats and boating gear. In addition, it was estimated that another $150 million was spent on such items as boat fuel, insurance, licenses, bait, ice, etc. Adding in such other expenditures as vehicles and fuel used by anglers brought the entire amount spent on recreational fishing in 1983-84 to $2.2 billion (not included in this figure, however, was money spent for hotel/motel etc.).

Membership in organized clubs or groups, however, is low, as only about 4 percent of Australian fishermen belong to such fishing organizations. In addition, about 10 percent of fishermen are solitary anglers. Overall, male anglers fished mostly with their friends (40 percent), while 30 percent fished with family members, 17 percent fished with other people (including coworkers), and 13 percent fished by themselves. Only 4 percent of females fished by themselves while 68 percent of them fished with their family, 20 percent with friends, and 8 percent with others.

Fishing Trips

The researchers also reported that male anglers made about 75 percent of the 48 million fishing trips taken by adults. In addition, they found that a relatively small number of the anglers accomplished a large proportion of the fishing effort—that those anglers who took 21 or more angling trips per year (18 percent) thus accounted for more than 62 percent of all fishing trips.

Why do Australians fish? The two top ranked answers were, respectively, to "relax and unwind" and "to be outdoors." The following three, ranked fairly evenly, included "for companionship reasons," for the "thrill or contest of catching fish," and to "catch fish for food."

Most of the respondents (71 percent) reported that their catch was eaten by themselves or their family, while 16 percent reported eating some and giving some away. About 5 percent released their catch.

[1]Note: This article is derived from reports in various Australian publications such as *Fins, Australian Fisheries*, and other periodicals and news items based on the two-report study "National Survey of Participation in Recreational Fishing" done by PA Management Consultants of Melbourne for the Australian Recreational Fishing Confederation.

Fisheries Management and Recreational Fisheries in Western Australia

B. K. Bowen

Management Directions

In July 1985 I published a Discussion Paper entitled "Arrangements for Entry to all Fisheries off and along the Western Australian Coast." The purpose of the Discussion Paper was to introduce a concept that resource access by professional fishermen should be limited along the entire coastline of Western Australia. Following a series of industry discussions, the Western Australian Fishing Industry Council (WAFIC) adopted the general approach of limited entry as a platform for sound management, but held the view that my proposal would result in arrangements which were too restrictive for the fishing industry.

WAFIC therefore submitted its proposal involving the development of some additional limited entry fisheries and also a strategy for managing developing fisheries. This approach has been adopted by Government, which means that by the end of 1987 all of the major fisheries along Western Australia will have a limited entry program. This involves approximately 20 different fisheries.

Furthermore, many of the management plans established as a result of Government and industry discussions will include a fishing capacity reduction mechanism to offset the growing fishing pressure resulting from better fishing boats, gear, and fish finding techniques. For example, the snapper fishery requires a 2 for 1 reduction in vessel access authorization transfer.

Organizational Structure

In Western Australia there are two major Councils representing the fishermen: The Western Australian Fishing Industry Council which represents the professional fishermen and is comprized of representatives of many Associations of Professional fishermen along the coast; and the Western Australian Recreational Fishing Council, which is the WAFIC counterpart, and represents the recreational fishermen of the State. There are a number of recreational fishing Associations involved such as the W.A. Division of the Australian Anglers Association, the W.A. Trout and Freshwater Angling Association, the W.A. Branch of the Australian Underwater Federation and so on. It is pleasing to note that representatives of these two Councils have met to discuss items of mutual interest in relation to the exploitation of fish resources.

Angling as an Important Source of Fresh Fish

As part of the study of Mercury in Sea Food a national consumer survey of fish and seafoods was undertaken in 1976-77. That survey produced some interesting and important information relating to the part played by recreational fishing in providing fish for the household. For Perth, the survey showed that 46 percent of the households interviewed had a member who went recreational fishing. That activity was closely allied with the source of the fresh fish supply to households. In fact, the survey showed that 47 percent of the householders interviewed stated that their source of fresh fish was either as a result of it being caught by a member of the household or as a gift. This places recreational fishing high in importance not only as a leisure pursuit but also as a source of fresh fish.

It is not surprising then that there is a continuing but proper debate on the use of fish resources by professional and recreational fishermen. However, in that debate it is important to recognize the legitimate role played by both groups of fishermen.

Fisheries Resource Users

There are professional fishermen who attempt to maximize their financial return on capital and labor and, in so doing, capture fish for sale to the wider community. Then there are the recreational fishermen who attempt to maximize their recreational pursuits and, in so doing, capture fish for themselves and their friends, or for the purpose of adding to the storehouse of knowledge of the fish stocks.

Both professional and recreational fishermen are responsible in their use of the fish resource, but those who are termed recreational fisherman but who attempt to operate in a professional manner are out of tune with both the true professional and true recreational fishermen.

For the most part the professional fishermen will be few in number but take the largest share of the combined professional and recreational catch. The very nature of their profession requires this to be so. On the other hand, the number of recreational fishermen is usually high, although their combined catch will usually be only a small fraction of the total catch.

Sound management must take into account the differing points of view presented by professional and recreational fishermen. The professionals tend to hold the view that they should have prime use of the resource because for them it is an industry of national importance, while the recreational fishermen tend to explain that the resource would be of greater value to the community if it were available to an increasing degree to their expanding number rather than be fished, and perhaps overfished, by a small number of people for financial return.

The history of development of most,

B. K. Bowen is Director of Fisheries, Fisheries Department, Perth, Western Australia. His article is from *Fins* 19(6), the bimonthly Fisheries Department journal.

but not all, of the fisheries in Western Australia is that their first exploitation has been by professional fishermen in estuarine or inshore areas close to the centers of population. Recreational fishing has followed and grown quite rapidly with a result that both professional and recreational fishermen are now important users of the coastal fish resources. In terms of fisheries management is is important that Governments recognize that both groups of users fulfil a responsible and proper role in the use of the fish resources.

The Common Property Nature of Fish Resources

A view commonly expressed is that a fish resource is the common property of the community and thus should be available in good measure to each member of the community. A view has also been expressed that, in terms of monetary return to the community, the most efficient use of a fish resource may well be through its increasing capture by recreational fishermen.

However, recent management decisions taken throughout Australia to introduce limited entry fisheries and individual transferable quotas have now to be taken into account when considering the sharing of the catch in the longer term by recreational and professional fishermen. Let me take the example of the output controls on the southern bluefin tuna by way of ITQ's. Currently the Australian quota for this species is 14,500 metric tons divided among the eligible fishermen. Quotas have been bought and sold on the basis of the owners of the quotas having a precise share of the total quota, whatever that might be from year to year. However, by way of a proposition let me now incorporate into that fishery an increasing recreational take of southern bluefin tuna to the extent that the production by recreational fishermen forms a significant, but not necessarily large, portion of the total catch. This would need to be taken into account in determining the annual quota and thus the share available to each holder of an ITQ.

The question would then be posed as to whether the reduced ITQ, as a result of increased recreational fishing, should set the pattern for future decisions when recreational fishing further increased or whether both parties should bear a portion of any future reductions required.

While the example used has related to output controls of ITQ's, the same principle is involved where input controls have been used, such as a limit on the number of pots in a rock lobster fishery.

It seems to me that constraints or reductions in fishing capacity, at least for some fisheries which are operating under a limited entry management plan and which are already heavily exploited, have to be shared by both the professional and recreational fishermen.

In summary, I believe that the common property definition of a fish resource has to be refined to incorporate the concept of a control in the total fishing capacity operating on a fish stock such that the control mechanisms relate to both professional and recreational fishermen. It seems to me that it would not be equitable to reduce the fishing capacity of the professional and recreational sector, with a view to reducing exploitation rate, but at the same time allowing the growth of the fishing capacity of the recreational sector. However, there will be exceptions to this generalized statement. For instance, estuarine fisheries are likely to gradually become more important for recreational fishing and less so for professional fishing.

Gear Definition

In the aquatic environment any fish can be taken by any gear type unless there is a Notice which gives attention to that fish or that gear type. In relation to both professional and recreational fishing there is a need to define the gear allowed.

Turning to recreational fishing, because this is what I am focussing on here, it is, I believe, necessary to describe the gear which is appropriate for use by recreational fishermen. For instance, should fishing nets now be regarded as recreational fishing gear, or it is appropriate that a recreational fishermen be allowed to have on his vessel long-line equipment including a power winch. I believe that both recreational and professional fishermen would welcome the development of more precise gear specifications for each of the two fishing sectors.

Recreational Preserves

While the general approach in Western Australia is to set rules on closed areas and seasons which apply equally to recreational and professional fishermen, there have been some decisions taken which either explicitly or implicitly favor recreational fishermen. For instance, in an area around Rottnest Island, a tourist island off Fremantle, recreational fishermen are allowed to take rock lobsters using their permitted two pots per person, but professional fishing in that area is not permitted. In other areas the gear regulations are so designed, such as prohibiting all gear likely to be used by a professional, that the only real use of the resource is by recreational fishermen. this occurs around jetties and similar structures. Finally, the Fisheries Act provides for a listing of species, such as the freshwater crustacean (marron), which shall not be taken for sale.

There have been a number of requests for rock lobster recreational preserves to be extended to the waters near the various fishing towns between Fremantle and Geraldton, but such requests have been declined on the basis of such action being not equitable in terms of sharing the catch in that particular circumstance.

In terms of sharing the catch it is pleasing to note that many of the important professional fisheries are in areas or on species which are not major sport fisheries. I refer to the prawn fisheries, purse seine fisheries, and the large-scale trawl fisheries. However, there are other fisheries such as the rock lobster, Australian salmon, and herring fisheries for which there will be a continuing debate on the proper sharing between professional and recreational fishermen.

As I said at another conference, making decisions on sharing the catch at a time when fishing pressure is increasing will require the patience of Job and the wisdom of Solomon. However, I trust that those who become involved in this debate will have sufficient of both of these attributes to provide for appropriate arrangements such that the recreational fisherman will be able to obtain a measure of recreational pursuit and the professional fisherman a measure of economic success.

Books on U.S. and Foreign Marine Recreational Fisheries

For 11 years an annual symposium has addressed various aspects of the U.S. marine recreational fisheries. They were cosponsored early on by the International Game Fish Association, National Coalition for Marine Conservation, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and the Sport Fishing Institute. The proceedings of each has been published—papers and discussions—and they provide an important and sound record of the problems, progress, research, and management of marine recreational fisheries.

The most recent published, **"Marine Recreational Fisheries 11,"** Proceedings of the 11th Annual Marine Recreational Fisheries Symposium, Tampa, Fla., May 1-2, 1986, edited by Richard Stroud, dealt with multi-jurisdictional management of marine sport fisheries, and associated problems and opportunities. The first volume of the series **"Marine Recreational Fisheries,"** edited by Henry Clepper, was published in 1977 and explored the basic nature and value of marine recreational fisheries from economic sociological, biological, and managerial points of view, defining the various MRF problems and offering recommendations for further investigation. The second, **"Marine Recreational Fisheries 2,"** identified major marine recreational fisheries problems—biological, economic, and social—and included recommended effective management practices based on scientific principles. Papers and discussions published in volume 3 analyzed marine recreational fishery research developments while those in volume 4 focused on the fisheries institutions and marine recreational fishery management, with a comprehensive and specific review of the proposals for saltwater angler licensing.

Volume 5 examined the biology, fisheries, research, and management of a single species, the striped bass, *Morone saxatilis*, while volume 6 concentrated on the sciaenid family (croakers, drums, weakfishes, etc.), an important recreational and commercial resource on all coasts. Volume 10 also treated a single species grouping, the Pacific salmon, *Oncorhynchus* spp., with 17 papers on a broad range of issues, covering the biology of important species, the Pacific salmon fisheries, the species' environmental needs, resource and habitat enhancement, as well as the local, regional, and international management policies.

In between, volume 7 discussed controversies and conflicts in marine recreational fisheries, while volume 8 assessed the status of fishery resources of primary recreational significance, and then profiled the related users, industry, and advocacy groups. Addressing and defining marine recreational fisheries development were the contributions to volume 9. Development goals were outlined and courses of action for public and private interests were suggested in order to move toward those objectives. Collectively, MRF series represents an important contribution to and record of the biology, economics, sociology, and the management of U.S. marine recreational fisheries. The cost is $15.00 per volume, but the entire set of eleven books is sold by the International Game Fish Association, 3000 East Las Olas Blvd., Fort Lauderdale, FL 33316-1616 for a package price of $50.00.

Yet another IGFA volume edited by Richard H. Stroud is **"World Angling Resources and Challenges,"** which encapsules the proceedings of the first world angling conference held in France in September 1984. The first hundred pages of the volume review a wide variety of national or regional angling reports—the species available, fishing organizations, fishing (angling) resources, types of angling available and methods employed, and much more. The second part presents several excellent reports on fisheries habitat—types needed, problems causing fish habitat losses or degradation (i.e., various pollutants and their sources and effects), and a call to sportsmen to guard their angling heritage.

Another section presents several avenues through which angling resources can be enhanced, i.e., habitat restoration, use of cultured fishes, artificial reefs and fish aggregating devices, etc. In addition, the volume provides insights into the needs for and uses of research, data requirements for management, economic evaluation of sport fishing, differences among anglers, game fish tagging programs, status reports on billfishes and bluefin tuna, Pacific salmon management in Canada, MRF management, and MRF development. The 390-page volume is available from the IGFA for $25 ($30 outside the United States).

Trophy Game Fishing Articles and Records

Publication of the volume **"1987 World Record Game Fishes"** has been announced by the International Game Fish Association, 3000 East Las Olas Blvd., Fort Lauderdale, FL 33316-1616. Over the years this has become something of a standard annual reference for serious marine (and freshwater) anglers. Each year it provides new, authoritative articles of wide interest, this time including: A review of New Zealand trophy angling opportunities by Mark L. Feldman; a history of big game fishing in the Bahamas by Dade W. Thornton; a clear and factual discussion of water friction and its effects on fishing line by Milton Shedd; South African angling from boats launched through the surf by Denis Mercer; getting kids hooked on fishing by Owen Taylor; and an in-depth look at medical problems anglers face and how to treat them by Gary Sherman.

And then there are the records—1,267 newly recognized record holders, contest winners, and special club members. For this issue, 619 new world records were approved by IGFA in 1986, and 513 anglers (out of 939 entries) won first, second, or third place awards in the annual fishing contest. In addition, 29 anglers

joined the exclusive Thousand Pound Club, and 106 others earned the 20-1, 15-1, 10-1, and 5-1 clubs. The volume also updates the listings in all-tackle, line class, and tippet class categories for over 150 freshwater and saltwater species—yet many categories remain open for new world records. New saltwater species added to the line class and fly rod world record lists are kahawai, *Arripis trutta*; bluefin trevally, *Caranx melampygus;* and mutton snapper, *Lutjanus analis*.

Additional data include the Guide to Fishes, with illustrations of and extensive data on all fishes on IGFA's record lists, a glossary, lists of U.S. state angling record keeping agencies and organizations, other worldwide recordkeeping organizations, and an inventory of worldwide tag-and-release programs for marine fishes. Paperbound, this 320-page book is available from the IGFA for $9.75 ($11.75 foreign).

Other Publications

Marine Fishes of Europe and the Mediterranean

Volumes II and III of Unesco's **"Fishes of the North-eastern Atlantic and the Mediterranean"** have now been published, completing the impressive three-volume reference which describes the main taxonomic features and biology of all of the known marine finfishes of that region—a total of 1,256 species from 220 families. As with Volume I, they include diagnostic keys to families, genera, and species. Entries for each species then include data on nomenclature, external morphology, reproduction, foods, habitat, and geographical description. Editors for the series are P. J. P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen, and E. Tortonese. More than 70 other specialists contributed to these authoritative and thorough volumes.

Volume I, of course, provided the key to all the FNAM families and included families 1-64 (Petromyzonidae to Anotopteridae). Volume II, then, includes families 65-161 (Mirapinnidae to Xiphiidae), while Volume III includes families 162-220 (Gobiidae to Linophrynidae). In addition, the final volume also presents the lengthy bibliography and indexes of common and scientific names. The texts of all are in English, though the Preface, Foreword, and User's Guide (in Vol. I) are in both English and French.

Now complete, the set constitutes an important major guide to the marine finfishes of Europe's waters and is an important ichthyological reference. Broadly, the scope of coverage is from the Mediterranean Sea to Madiera, the Azores, then north to Greenland and eastward to Novaya Zemlya. The family key (Vol. I), valid only for the covered region, includes a representative drawing. All species are included from all habitats, including estuaries, lagoons, and brackish waters, and from the continental shelves to the abyssal depths. Excellent species drawings and distribution maps are included. This comprehensive work will be an excellent reference to the region's fishes. Hardbound, Volume II is paginated from 517 to 1007 and Volume III from 1015 to 1473. In the United States, each volume is priced at $45 and they are available from the Unesco distributor, Bernan-Unipub, 4611-F, Assembly Drive, Lanham, MD 20706-4391. Those overseas may wish to contact the Librairie de l'Unesco, 7, place de Fontenoy, 75700 Paris, France (cost 250 FF per volume).

A Manual for the Commercial Fisherman

The second edition of the **"Fishermen's Handbook"**, edited by Rear Admiral C. P. R. C. Branson for the British Marine Mutual Association, Ltd., has been published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. Since first published as the "Fishermen's Handy Billy," each edition has been considerably revised, to keep up with new legislation and advancements in technology and the fishing industry.

Indeed, this edition has again been considerably revised, primarily to stress safety and enhance the fisherman's survival in case of an emergency. For instance, detailed descriptions of well-known fishing methods have been replaced with chapters on specific hazards relating to bottom trawling, purse seining, scallop dredging, gill netting and longlining. In addition, the book provides more guidance for those navigating outside U.K. waters. Also broadening its usefulness is its concentration on subjects of more universal interest instead of on British regulations or matters of local interest. While volumes have been written on each of the chapter topics, this handbook will give the fisherman clear, succinct guidance on the basic rules for safe and efficient operation of a fishing vessel.

The volume is divided into six parts. Part I, on management and maintenance of the vessel, presents a good discussion of vessel stability. Part II, navigation, discusses maritime buoyage systems (IALA), tides and tidal streams, useful charts and publications, navigation instruments and equipment, and discusses coastal navigation, electronic navigational aids, and ocean navigation.

Part III reviews watchkeeping and shiphandling, including material on meteorology, collision avoidance rules, the international code of signals, submarine telegraph cables and offshore installations and safety zones. Part IV, fishing operations, again, stresses the safety aspects of commercial fishing operations, with various gears. Part V then goes into more depth on safety and survival at sea, including transmission of danger messages, and distress calls, rescue procedures, visual signals, use of inflatable liferafts and personal survival at sea. Likewise, fire prevention and fire fighting techniques are reviewed, along with other emergencies such as explosives, man overboard, grounding and refloating vessels, beaching a damaged ship, and approaching and towing a disabled vessel. Finally, Part VI deals with anchors and cables and ropes, knots, bends, hitches, slings, and tackles. Several appendices tell how to find the distance of objects at sea, determine tide height between high and low water, finding a distance off with the sextant, recommended distress transmission procedures, tables of strengths of natural fiber ropes, and

more. In addition, 8 pages in color show the International Code of Signals, IALA buoy marks and maritime buoyage systems for Regions A and B, and lights and shapes to be shown for collision avoidance. Indexed, the 320-page paperbound volume is available from the publisher for £15 or, in North America from Bernan-Unipub, 4611-F Assembly Drive, Lanham, MD 20706-4391 for $27.00 (order no. FN126).

Another Look at the "Silent Spring"

"Silent Spring Revisited," edited by Gino J. Marco, Robert M. Hollingworth, and William Durham, has been published by the American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC 20036. In part, it was written, mostly by knowledgeable scientists, to try to answer the questions "Was Rachel Carson right?" and "Where do we stand now?", with respect to the issues she raised of environmental pollution with various chemicals, and especially pesticides and herbicides. The results are both interesting and informative and, of course, there is no one simple answer.

Carson was, first, a fine marine biologist, and an excellent writer, and her first books, like "Under the Sea Wind" and "The Sea Around Us" reflected that expertise. But it will be "Silent Spring" for which she will be remembered and in which she warned of the problems for fish, wildlife, and humans of the misuse and overuse of dangerous chemicals. Now, this new ACI book takes a 25-year look backward, assesses the present and future. In short, the authors believe that most all the problems that Rachel Carson brought up in her 1962 book "Silent Spring" are at least in some stage of correction. The 12 chapters are divided into five sections, with the first relating how Carson came to write her book.

Other chapters describe the origins and evolution of government policies regulating pesticides. Then, separate chapters discuss specific environmental effects of pesticides on marine and freshwater species, wildlife, humans, and on the safety of groundwater. Also reviewed is the evolution of analytical chemistry with regard to the ability to identify and quantify trace quantities of specific chemical pollutants. Other chapters discuss both sides of the debate on the dangers vs. the benefits of pesticides and on high agricultural productivity vs. environmental costs. A concluding chapter summarizes the sometimes conflicting issues. The volume is reasonably balanced in perspective and presents an interesting and useful and easily readable look at what have been at times a very controversial issues. Though most of the chapters have been written by scientists, it is written in a style that knowledgeable laymen can utilize. The book is based on a symposium organized by the Pesticide Subcommittee of the ACS Committee on Environmental Improvement "to address the issues that Rachel Carson raised and focus on their pertinence for the past, present, and future." Indexed, the 214-page volume is sold by the Society for $29.95 (U.S. and Canada), $35.95 (export) in the clothbound edition; the paperbound edition costs $17.95, U.S. and Canada, and $21.95, export.

Natural Resource Economics, Management, and Policies

Publication of **"Natural Resources Economics and Policy Applications,"** edited by Edward Miles, Robert Pealy, and Robert Stokes, has been announced by the University of Washington Press, P.O. Box C-50096, Seattle, WA 98145-0096. The volume is subtitled "Essays in Honor of James A. Crutchfield," and contains original contributions by scholars who are Crutchfield's peers, colleagues, and former students. Crutchfield is well known for his scholarly contributions in natural resource economics, especially in the field of fisheries. The contributions are broad in scope, dealing with fisheries, water resources, and related policy decision making.

The book's central theme is a concern for the contributions of economics and economists to natural resource policy-making, and it is divided into four parts. Part I, on economics and policy, presents papers reflecting on the interaction of economics and policy. Part II discusses substantive problems of policty and management with a focus on fisheries management and development and on water resources policy. Part III contains papers on analytical and methodological issues, most utilizing econometric models and dealing either with fisheries or environmental issues. And Part IV discusses general problems of bringing specialized knowledge to bear on policy making with respect to natural resources.

And, of course, many of the papers deal specifically with commercial and/or marine fisheries issues. Anthony Scott presents an essay on fisheries catch quotas and shares in fish stocks as property rights. Giulio Pontecorvo focuses on the interaction between changes in supply and demand and the common property conditions of fisheries resources by reviewing the historical dynamics of the U.S. Georges Bank fisheries.

Francis T. Christy, Jr., discusses the special characteristics and problems of small-scale fisheries management in developing nations, while Rowena Lawson deals with the general problem of appropriate strategies for fisheries development and elaborates the options that are available to coastal states for developing and managing their fisheries resources. The Federal fisheries law enforcement program is then described and evaluated by Jon Sutinen and Timothy Hennessey, who suggest strategies for improving compliance with regulations.

Another paper by Lee G. Anderson discusses economically optimal total allowable catches in the absence of stock-recruitment relationships, while Gardner Brown looks at static vs. dynamic models in fishery management. The final section presents three papers which discuss the general problems of bringing specialized knowledge to bear on policy making with respect to natural resources. An appendix presents selected biographical data on Crutchfield and a bibliography of his publications.

Compared with other fisheries economics volumes, the presentations are rather wide-ranging in scope, but should be of interest to noneconomists as well as to economists. Indexed, the 440-page hardbound volume costs $30.00 and is available from the publisher.

Scientific and Technical Publications on Marine Recreational Fisheries

Listed below are reviewed and published scientific and technical reports on various aspects of marine recreational fisheries. Not included are journal articles, pamphlets, poster session materials, or other presentations. The reports have been compiled from listings supplied by the various institutions, laboratories, agencies, offices, or libraries, and is not represented as a complete compilation of such items. Any additions or corrections may be addressed to the Editor, *Marine Fisheries Review* at the NMFS Scientific Publications Office, Bin C15700, Seattle, WA 98115.

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Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

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Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

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Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

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In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

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